Potential of shared micromobility at Park and Ride locations in the Netherlands

Master Thesis

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Colophon

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Preface

This is the final report on my master thesis as part of my master's program Civil Engineering and Management at the University of Twente. For my master thesis, I studied the potential of shared micromobility at peripheral Park and Ride locations in the Netherlands. This report is the result of the research I conducted between September 2023 and July 2024 in cooperation with Royal HaskoningDHV. During this period, I learned a lot about shared mobility from previous research projects and meetings with experts on this topic, but also what is involved in running a survey by myself.

I would like to thank my external supervisor of Royal HaskoningDHV Simon Krikken for making this research possible and guiding me throughout the process. The meetings gave me insights that were important for my research and made it possible for me to achieve this result. Besides, I would like to thank all my colleagues at Royal HaskoningDHV who provided me with experiences of real-life projects related to the topic of my research. In particular, I would like to thank Mathijs Schoenmakers for getting me in touch with the municipality of Maastricht.

With the help of Rob Lamers of the municipality of Maastricht and Laura Gorissen of the programme office Zuid-Limburg Bereikbaar I was able to distribute the survey for this research also via online resources. This has helped me to get a sufficient response for which I would like to thank them.

Additionally, I would like to thank my supervisors of the University of Twente Karst Geurs and Anna Grigolon for providing me with feedback and insights for the research.

Lastly, I would like to thank my family and friends, for giving me support during my thesis project.

Tom van Hal

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Abstract

To overcome problems related to urbanization and the environment, a shift from private vehicle use to more sustainable forms of transport could have a great impact (Ma et al., 2020). An essential link in the mobility transition towards sustainable and multimodal transport is the development of mobility hubs, that facilitate the integration of shared mobility and public transportation. This study aims to investigate the potential of shared micromobility at peripheral Park and Ride (P+R) locations in the Netherlands. First, a spatial analysis is conducted to gain insight into the characteristics of a P+R in terms of location, public transport network and presence of shared mobility. With the information from the spatial analysis, a multi-criteria analysis is conducted to select two suitable study locations for this research. At both selected locations, a survey is distributed to gain insight into the characteristics of the P+R users and the factors influencing the intention to use shared micromobility at a peripheral P+R location. This is done through a regression analysis. An accessibility analysis is conducted to compare the accessibility of public transport and shared micromobility considering time thresholds (10, 20, 30 minutes) and cost thresholds (€2.50, €5.00, €7.50). The spatial analysis showed that at 77% of the locations, at least one type of shared mobility is available. The results of the survey (N=750) showed that the users are primarily female, older (45+), highly educated and part-time employed. Only 1.9% of the respondents indicated that they currently use a shared bike as a last-mile transportation mode. However, the intended use for shared micromobility is higher, as 34.4% of the current public transport users (N=631) intend to use at least one type of shared micromobility (i.e. shared bike, shared e-bike, shared e-moped). Using an ordinal logistic regression model, it was found that someone with prior shared mobility experience has a significantly higher intention to use shared micromobility. Furthermore, the payment methods and the availability of a transport mode at a P+R were found to be significant predictors for someone with a positive intention of using the shared e-bike and shared bike, respectively. Both predictors relate to the type of micromobility system that is available at a P+R. This implies that these characteristics influence the use of shared micromobility. As the majority of the survey sample has no intention to use shared micromobility, and the regression analysis indicates that people with walking difficulty have a lower intention of using a shared bike, the public transport connection is important to facilitate each P+R user. The accessibility analysis comparing the modes with a time threshold showed better accessibility for all shared micromobility types than public transport. However, comparing the accessibility of the modes for a cost threshold shows that shared micromobility is more expensive. For a low cost threshold, public transport has better accessibility. Overall, the analysis of the survey and the accessibility analysis show that there is potential for shared micromobility at peripheral P+R locations.

Executive Summary

To overcome problems related to urbanization and the environment, a shift from private vehicle use to more sustainable forms of transport could have a great impact (Ma et al., 2020). An essential link in the mobility transition towards sustainable and multimodal transport is the development of mobility hubs, that facilitate the integration of shared mobility and public transportation. Shared micromobility is an umbrella term that includes the shared use of a bike, e-bike, e-moped or other low-speed modes. It enables users to have a transportation mode on an as-needed basis for a short period (Shaheen et al., 2019). It could therefore be a suited alternative to public transport for the first or last part of a journey at a P+R location. However, it is currently unknown whether people are willing to use these modes or continue using public transport connections. Therefore, more information is needed on the user characteristics and intentions of people who potentially will choose shared micromobility. Besides, it is unknown if shared micromobility at a P+R would improve the overall accessibility to the destinations of the users since public transport might not reach a part of important amenities. Therefore, this research aims to investigate the potential of shared micromobility at peripheral Park and Ride locations in the Netherlands. Peripheral P+R locations aim to intercept car traffic heading towards the urban centre and are usually located at the edge of a city (Rongen et al., 2022). Since shared micromobility is currently mostly provided in urban areas and is more used for last-mile trips compared to first-mile trips (CROW, 2024b), it is chosen to only focus on peripheral P+R locations and thus the potential of shared micromobility as last-mile mode.

To achieve the research objective, the following research questions are formulated:

1. What are the characteristics of peripheral P+R locations in terms of location, public transport network and presence of shared mobility?
2. What are the characteristics of P+R users at the studied locations?
3. What factors influence people's intention to use shared mobility as a last-mile transportation mode at a P+R location?
4. What is the difference in accessibility between shared mobility and public transport as last-mile transportation modes at a P+R location, considering cost and time thresholds?

Spatial Analysis P+R Locations
The spatial analysis of peripheral P+R locations in the Netherlands is the first part of the methodology of this research. For this spatial analysis, characteristics of peripheral P+R locations in the Netherlands are analysed in terms of location, public transport network and presence of shared mobility. Various data sources are used to obtain information from the P+R locations, for example, the Dashboard Deelmobiliteit (CROW, 2024a) that provides an overview of the real-time location for shared micromobility. The gathered information is used to answer the first research question and to conduct a multi-criteria analysis (MCA) to select two suitable study locations. These study locations are used to answer the other research questions. Before conducting the MCA, the P+R locations are checked on three selection criteria: (I) only P+R locations with shared micromobility available are considered, (II) only P+R locations with a public transport stop and shared micromobility within 200 metres of the parking facilities are considered, and (III) P+R locations should be within 4 kilometres of the city centre. The P+R locations that meet each criterion were rated on the following attributes:

- The distance from national or regional roads to the P+R location
- The available public transport modes and frequency to the city centre
- The available shared mobility modes and type of service
- The travel time of public transport and shared modes to the city centre

The spatial analysis showed there are 62 peripheral P+R locations in the Netherlands, most are located in the Randstad area. In the Randstad area, most P+R locations have a metro, tram or multiple public transport connections. Outside the Randstad area, the P+R locations mostly have a bus connection. The public transport frequency has a maximum of every 15 minutes for 95% of the P+R locations. This observation is in line with the guidelines for developing a P+R location of the CROW (2005), which describes that a public transport connection with a frequency of at least 4 times per hour is desirable. At 47 of the 62 locations shared mobility is present, and at 24 locations more than one shared mode type. Focusing on the location of the peripheral P+R locations, 84% of the locations lie within 2 kilometres of a national or regional road. As a P+R location is ideally located close to the main road network (CROW, 2005; VenhoevenCS & Rijkswaterstaat, 2020), this result shows that the majority of the locations have a desired location. 65% of the locations lie within 6 kilometres of the city centre. Finally, for 49% of the peripheral P+R locations with at least one shared mode, public transport is a faster transportation mode to reach the city centre.

Using the information of the peripheral P+R locations for the MCA, only 11 of the 62 peripheral locations fulfil the selection criteria for a suitable study location. This is mainly because the P+R locations are located more than 4 kilometres away from the city centre. This implies that for most P+R locations shared micromobility was originally not considered as a last-mile transportation option in addition to public transport when the P+R locations were realised. This can be explained because most P+R locations were developed before 2010 (Rongen et al., 2022) and shared mobility was rarely used at that time (KiM, 2021a). After rating each attribute, P+R Maastricht Noord and P+R Deutersestraat ('s-Hertogenbosch) were found to be the most suitable locations for this study according to the MCA. These locations are used to distribute the survey, analyse the survey results for, and conduct an accessibility analysis.

Survey
A survey has been developed for the remaining research questions to obtain data from the P+R users. The aim of the survey is twofold. On the one hand, it should give insight into the user characteristics and attitudes towards last-mile transportation modes of the P+R users. On the other hand, it is aimed to identify factors that significantly influence the use of shared micromobility at a P+R as a last-mile transportation mode. The survey is distributed among the two P+R locations by handing out flyers with a QR code, which leads to a digital survey. The developed survey is based on a review of questionnaires from previous studies related to travel behaviour, shared mobility or mobility hub usage, and consists of the following parts:

- **A. Travel behaviour**
  - **A1. General travel behaviour:** questions related to the usage frequency of public transport and shared mobility in the past year, and the physical ability to use shared micromobility.
  - **A2. P+R travel behaviour:** questions related to the last-mile trips from the P+R location to the destination of the respondents, such as the transport mode used, their motivation for using that mode, and their intention towards other last-mile transportation modes.
- **B. Trip characteristics for mode choice:** for eight trip characteristics (e.g. travel time and travel costs) it is asked how important the respondents rate them regarding mode choice for travelling from the P+R to their destination, on a 5-point Likert scale.
- **C. Socio-demographic information:** questions about the socio-demographic information of users, for example, age and education level.
- **D. Digital skills:** questions relating to the digital skills of respondents, such as access to a mobile phone and performed activities on the mobile phone (e.g. planning trips, payment activities).

The descriptive statistics of the survey are analysed to answer the second research question. The results of the survey (N=750) showed that the users are primarily female, older (45+), and part-time employed. Besides, the majority (96.1%) have a Dutch background and are highly educated (61.4%). Focusing on the frequency of using the P+R locations, 39.1% of the respondents indicated using the P+R 1 to 5 days per year, and only 6.9% use the P+R 4 or more days per week. The majority of the non-frequent users have "shopping" as the purpose, for the frequent users the purpose is "to and from work". Furthermore, the distribution on the current use of last-mile modes shows that 81.9% use the bus to go to their destination, and only 1.9% of the sample uses a shared bike. The intention of P+R users to use shared micromobility is higher compared to the current use. For the current public transport users (N=631), 34.4% intend to use at least one of the shared modes (i.e. shared bike, shared e-bike, shared e-moped) when public transport is not available at the P+R location. Finally, the majority of the respondents of both P+R locations have a destination in the city centre.

Data Analysis

The third part of the methodology encompasses the data analysis that is conducted to answer the third research question. A regression analysis is conducted, which aims to identify factors that significantly influence the intention to use shared micromobility at a P+R location. It is a statistical method used to analyse variables that might influence an objective and to determine important factors and those that can be ignored (Qualtrics, 2023). The dependent variables that are considered for this research are: (I) The intention to use a shared bike, (II) the intention to use a shared e-bike, and (III) the intention to use a shared e-moped. The intended use was asked in the survey with a 5-point Likert scale, ranging from very unlikely to very likely. As the outcomes of the dependent variables are in a defined order, it is chosen to apply an ordinal logistic regression model.

The regression analysis showed that for each type of shared micromobility (bike, e-bike and e-moped) different predictors significantly influence the intention to use it. Only the prior experience of shared mobility usage was found to be significant for all three shared modes and describes that someone with experience has a higher intention of using a shared mode. In addition, the walking difficulty and availability of transport modes were found to be significant for the intention to use a shared bike. The significance of the latter trip characteristic illustrates that the type of shared micromobility system applied at a P+R location is an important aspect concerning the potential of shared micromobility at a P+R location.

The migration background and the type of payment methods at the P+R location are significant predictors of the intention to use a shared e-bike. Payment for using a shared mode works currently often with an app. The significance of this variable implies that providing multiple payment options for using shared modes can positively influence shared micromobility usage at a P+R.

It was found that younger people have a higher intention to use a shared e-moped than older people. Besides, someone who thinks to have the ability to use an e-moped has a higher intention to use a shared e-moped. Furthermore, someone who values the facilities at a P+R location as important has a higher intention to use a shared e-moped.

Accessibility Analysis

The final part of the methodology is an accessibility analysis that compares the accessibility of shared micromobility and public transport at the two P+R locations, to answer the last research question. To compare the accessibility, the cumulative opportunities accessibility measure is applied. This measure counts the number of opportunities which can be reached within a set time or cost threshold (Geurs & van Wee, 2004). To express accessibility, the number of destinations indicated by the respondents of the survey and the points of interest (POI) that can be reached within the thresholds are considered as opportunities.

As described, two types of thresholds are used in the accessibility analysis: a time and cost threshold. Three times are used to draw the service area: 10, 20 and 30 minutes. By analyzing three time thresholds, it is possible to see how accessibility changes for the different modes. In addition to the time thresholds, three cost thresholds are set. The accessibility of public transport is chosen as a reference in this analysis, so one could analyse what the accessibility would be for a shared mode given the price for travelling with public transport as the threshold. The cost thresholds set are: €2.50, €5.00 and €7.50. The lower and middle prices are in line with the current prices for the P+R in Maastricht and 's-Hertogenbosch, respectively. As users of the P+R can travel with public transport for a fixed price (the price is not dependent on the time you use the bus), it is assumed that the number of opportunities that can be reached by public transport is for each cost threshold equal to the number that can be reached within a time threshold of 30 minutes.

It was found that public transport results in the best accessibility for the lowest time or cost threshold compared to shared micromobility. For the other time thresholds, one could access more destinations or POI with shared micromobility according to this analysis. However, the analyses for the cost thresholds show that especially for a shared micromobility system which applies a price schedule where the price increases for every minute you travel, public transport or a fixed-price system can be a cheaper option. It should be noted that external reasons for the choice of transport mode are not yet included in this analysis, such as weather conditions or travel motives (e.g. having lots of luggage when going shopping). Although travel time and travel cost were not identified as significant factors in the regression analysis, the accessibility analysis shows that the accessibility differences between modes can be large and the accessibility for cost and time thresholds are different.

Discussion and Conclusion

Overall, given the methodology used in this study, the analysis of the survey and the accessibility analysis show that there is potential for shared micromobility at peripheral P+R locations. Although the factors travel time and travel cost were not found to be significant in the regression analysis, the motivators for using a last-mile mode indicate that these factors do matter for P+R users. Besides, using the variables as thresholds in the accessibility analysis is a nice visual way of comparing transportation modes and differences between travel time and cost in accessibility. The regression analysis found that people with walking difficulty and people who do not know if they are able to use a shared e-moped have a lower intention to use shared micromobility. Because of mobility limitations, they might not be able to use a shared micromobility at all. Therefore, maintaining the public transport connection is important to facilitate this target group at the P+R. Besides, the accessibility analysis shows that shared micromobility is in general more expensive than public transport, so low-income groups might also prefer public transport over shared micromobility.

The regression analysis also found that someone who values the availability of transport modes as important has a higher intention to use a shared bike. Besides, it was found that someone who values payment methods at a P+R as important has a higher intention to use a shared e-bike. Both characteristics relate to the type of shared micromobility system that is facilitated at the P+R, for example, a station-based or free-floating system. Considering also the higher accessibility for the lowest cost threshold for a station-based system compared to free-floating systems, it seems that providing a station-based shared micromobility system is the most suitable at a P+R location. In addition, a flanking policy that could stimulate the use of shared micromobility at a P+R location is the inclusion of travelling with a shared mode into the travel options of the P+R tariff.

Contents

1 Introduction

The number of people living, working and recreating in cities has increased greatly over the past years. This increase in activities in and around cities affects their environment and livability (Natuur & Milieu, 2020). The transportation of people and goods plays an important role, as fossil-fuel-powered means of transport harm health and the environment (Natuur & Milieu, 2020). Shifting from private vehicle usage to more sustainable forms of transportation could help to overcome the problems related to urbanization and the environment (Ma et al., 2020). The development of mobility hubs is an essential link in the mobility transition towards sustainable and multimodal transport. Mobility hubs are physical locations that facilitate the integration of different shared and public transportation modes to optimize the traveller's journey (CoMoUK, 2019; Provincie Noord-Holland, 2022). Hubs could facilitate better liveability and accessibility to low-traffic areas (i.e. city centres), as well as maintain and strengthen the accessibility of rural areas (KiM, 2021b). The mobility hub concept partly builds on previous related transport node concepts, such as Park and Ride (P+R) facilities and Transit Oriented Development (TOD) initiatives (KiM, 2021b; Rongen et al., 2022). Current mobility hub projects aim to go beyond the earlier concepts by integrally developing the position of mobility hubs in the mobility system and spatial environment. This is done by combining shared modes, new technology and non-mobility services (KiM, 2021b).

This study aims to investigate the potential of shared micromobility at P+R locations in the Netherlands. A P+R location is a connection point for private vehicle users to park on the outskirts and access the city centre using public transport (Ortega et al., 2021b; Rongen et al., 2022). According to mobility hub typology, a P+R is a form of a transfer hub (or city edge hub), characterized by its (inter)regional scope and transfer opportunities between the city centre and outer areas (Weustenenk & Mingardo, 2023). Looking at the current P+R locations in the Netherlands, it is found that the average occupancy rate is only 60% over all provinces with even lower occupancy rates in eight provinces (CROW, 2023b). Further development of P+R to fully-fledged transfer hubs with shared mobility and other facilities (e.g. package point and charging facilities) is described as a promising measure by the studies of Kwantes and Scheltes (2021) and Rongen et al. (2022), which could increase the occupancy rate of a P+R. Besides, multiple municipalities indicate that they want to provide more sustainable transportation modes close to the origin of travellers and indicate that P+R locations could be suitable for this mean (Groene Metropoolregio et al., 2021; Mecanoo & Gemeente Dordrecht, 2022).

Shared micromobility is an umbrella term that includes the shared use of a bike, e-bike, e-moped or other low-speed modes. It enables users to have a transportation mode on an as-needed basis for a short period (Shaheen et al., 2019). Shared micromobility is proposed to be an effective measure to reduce vehicle ownership in urban areas and can be used as a first and last-mile transportation option (CROW, 2021; Oeschger et al., 2020). It could therefore also be a suited alternative to public transport for the first or last part of a journey at a P+R location. However, it is currently unknown whether people are willing to use these modes or continue using public transport connections. Therefore, more information is needed on the user characteristics and intentions of people who will potentially use shared micromobility. Besides, it is unknown if shared micromobility at a P+R would improve the overall accessibility to the destinations of the users since public transport might not reach a part of important amenities. Currently, little research is available on the potential of shared micromobility at P+R locations in the Netherlands. Therefore, this research aims to fill a knowledge gap on this topic.

2 Literature review

A literature review is conducted to provide some context into relevant topics related to this research. Section 2.1 discusses the various definitions of mobility hubs, which will give more insight into the function of each hub type. Besides, it clarifies the characteristics of a P+R as a mobility hub compared to the other hub types. Section 2.2 discusses the P+R concept and user- and transportation characteristics that influence the choice for using a P+R location. This also relates to the theory of mode choice factors that influence people to use certain transportation modes. Section 2.3 discusses the concept of shared micromobility and the user- and transportation characteristics that influence the use of shared modes. Section 2.4 describes how accessibility can be evaluated and how this is currently applied in shared mobility-related research. Lastly, section 2.5 addresses the research gap and discusses a conceptual framework summarizing a part of the literature review that is used for the method of this study.

2.1 Mobility Hubs

The concept of mobility hubs reached popularity over the past few years. This year, for example, hubs popped up in the city of Enschede for shared vehicles (Gemeente Enschede, 2023). Conducting a literature review through various academic and grey literature shows that there is no single definition for the concept "mobility hub". Besides, multiple terms are used for the same concept, such as intermodal hub (Amoroso et al., 2012), eHUB (Bösehans et al., 2023; Van Gils, 2020) and mobility station (Wulfhorst et al., 2017).

All definitions of mobility hub emphasize its role as a physical location or place that facilitates the seamless transfer between different transportation modes, enhancing intermodality and providing facilities to optimize the traveller's journey. It can therefore be argued that conventional bus and train stations are also mobility hubs, as these places fit in definitions of literature that only touch on this characteristic (CoMoUK, 2019; CROW, 2021; Goudappel & APPM, 2021; KiM, 2021a; Mobiliteitsalliantie, 2020; Wulfhorst et al., 2017). At train stations, travellers can mostly transfer to other forms of public transport, such as the bus, or by heading to their bicycle. The latter also holds for many travellers at bus stops.

Next to the connecting role of mobility hubs, some literature sources also point out the sustainability role of hubs. The report of Natuur & Milieu (2020) defines it as *"a high-quality physical location that combines a diverse range of sustainable and active means of transport with a pleasant place to stay"*. When using the term eHUB, it implies that shared electric modes are present, which strengthen the sustainable role of a mobility hub (Bösehans et al., 2023; Van Gils, 2020).

In addition to these characteristics, many literature sources describe a mobility hub as a place where at least one shared mode of transport is available. For example, according to Blad et al. (2022), a mobility hub is *"a physical point in which a convenient transfer is offered between the available modalities, which includes in any case shared mobility, and possibly other private and public transportation"*. Coenegrachts et al. (2021) highlight in their definition of a mobility hub that both new and conventional mobility services are clustered at a physical location. Geurs et al. (2023) add to this that public transport is available within walking distance of the other shared transportation modes. For this research, the definition of Blad et al. (2022) and Geurs et al. (2023) will be applied.

2.1.1 Typology

Different types of mobility hubs are known, as multiple studies categorize them based on their physical characteristics. The Mobiliteitsalliantie (2020) distinguishes hubs mainly based on geography (between city centre and region) and the physical transfer function (people or goods). Another categorization is made in the study of Van Gils (2020) that categorizes hubs based on the position of a location within the local transportation network.

Weustenenk and Mingardo (2023) identified six types of mobility hubs in their paper. The hubs are categorized based on the quantity and complexity of transport modes, services, and facilities. The lowest level of services & facilities is parking places only, whereas the highest level also includes many non-mobility related services such as package pickup points and retail. Regarding transport modes, the level of complexity starts with shared (e-)bicycles and shared (e-)mopeds and ranges to high-frequency intercity trains for the highest complexity level. The following hub types are identified by Weustenenk and Mingardo (2023):

- **Community hub:** accessible for a selective group of users (e.g. employees or residents of a flat complex) and usually located in privately owned areas. The hub type is characterized by a limited number of facilities and services and offers mostly only shared (electric-)cars, -bicycles, and -mopeds.
- **Neighbourhood hub:** usually located near neighbourhood amenities and local services are provided (e.g. package pick-up points). Shared transportation modes are offered in combination with a public transport connection, and users mostly access the hubs on foot or by bicycle.
- **Suburban/Regional hub:** focusing on the accessibility of the suburban area and are generally characterized by the necessity for private vehicles to reach them. Suburban hubs typically feature public transport stops like bus stops and small railway stations.
- **City edge/Transfer hub:** characterized by its (inter)regional scope and is often developed with a focus on serving as a Park and Ride (P+R) location, that offers a transfer between cities and their outer areas. Public transport that connects the city centre with the outer area is available, as well as infrastructure for private vehicles (i.e. parking spaces).
- **City district hub:** focuses on the liveability within the urban district and the clustering of functions. In comparison to neighbourhood hubs, they offer a higher level of services and transportation choices. Both shared mobility services and public transport options are available.
- **City centre hub:** centrally located in the city centre, so accessible by active transportation modes. It is typically the form of a major railway station, so it provides a comprehensive range of transportation modes and services/facilities.

As part of the SmartHubs project, the paper of Geurs et al. (2023) considers not only the physical dimension for a hub typology but also a digital and democratic dimension. An integration ladder is developed that allows comparing different hubs with different services, understanding potential impacts and promoting the integration of societal goals into mobility hub developments. Each of the three dimensions has 5 levels (from 0 to 4) that help to distinguish smart mobility hubs from the pool of hubs. The SmartHubs Integration Ladder is shown in Figure 1.

The physical dimension of the ladder assesses the physical connectivity of mobility modes with other functions at the locations of the hubs. It highlights that walking accessibility to other services, having multiple shared modes in the hub, and having a design that is visible without physical barriers are of great importance. The digital dimension involves the process of integrating information onto a single digital platform and enabling various information platforms to access data using a standardized format. The digital integration levels build upon the existing Mobility-as-a-Service (MaaS) framework by incorporating digital accessibility and universal design principles. Lastly, the democratic dimension is grounded in the principles of participatory governance, aiming to involve residents in the development of mobility hubs to create more inclusive and user-centric facilities. The approach emphasizes the rights and duties of both givers and takers, allowing for a more nuanced assessment of ongoing processes (Geurs et al., 2023).

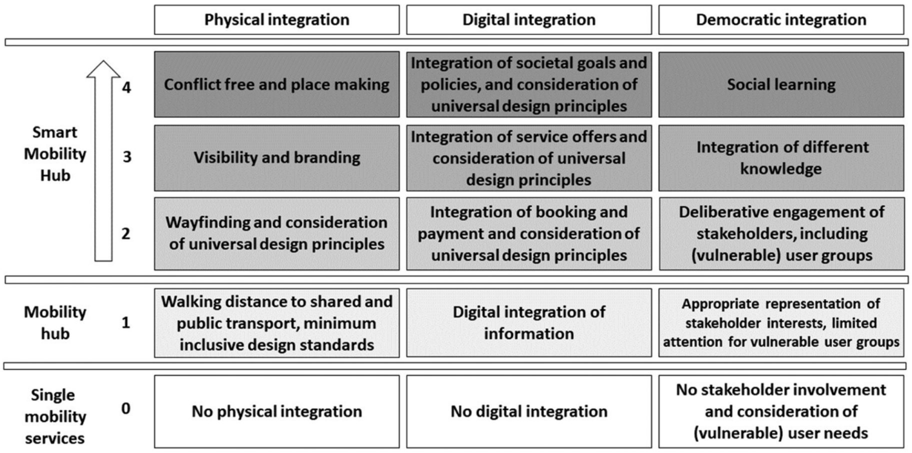


Figure 1: The SmartHubs Integration Ladder (Geurs et al., 2023)

2.2 Park and Ride (P+R)

As described in the study of Bertolini (1999), there is a clear relation between node and place, so between infrastructure and transportation, and the built environment. Park and Ride (P+R) is a node-place concept that has been known for decades and has similarities with the concept of mobility hubs (Rongen et al., 2022). A P+R is a connection point that allows modal shift for private vehicle users to switch to public transport modes, for example, tram or bus (Ortega et al., 2021b). The concept emerged in the 1920s in the US and was first introduced in the Netherlands in 1979 (Mingardo, 2013; Ortega et al., 2021b). Currently, the Netherlands has 443 P+R locations which shows that the concept is widely implemented (CROW, 2023b). The main objective for policymakers to implement P+R is to reduce the number of cars entering the city centre by encouraging car users to take public transport as a part of their journey. This should lower congestion levels and improve urban accessibility, which might even lead to a reduction in the total vehicle kilometres travelled (VKT) and thus in a reduction of emissions by private vehicles (Huang et al., 2019; Ortega et al., 2021b; Zijlstra et al., 2015). Two main types of P+R can be distinguished based on their location (Mingardo, 2013; Zijlstra et al., 2015):

- **Remote P+R** have an *origin* function, where public transport (PT) is used for the main part of the journey and the car is only used to access the PT service. These P+R are usually located in suburban residential areas and primarily focus on alleviating congestion and reducing emissions along the main road network (Rongen et al., 2022). Figure 2 illustrates the function of a remote P+R location.
- **Peripheral P+R** have a *destination* function and aim to intercept car traffic heading towards the urban centre. The main mode is the car and PT services are only used to cover the last kilometres. These P+R are usually located at the edge of a city and focus on improving livability and reducing congestion associated with urban traffic (Rongen et al., 2022). Figure 3 illustrates the function of a peripheral P+R location.

Figure 2: Illustration remote P+R location

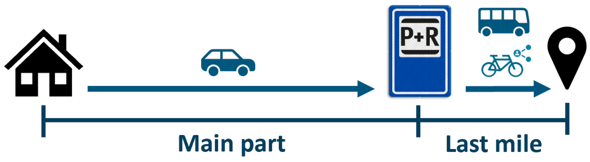


Figure 3: Illustration peripheral P+R location

2.2.1 User- and Transportation Characteristics

Multiple studies have previously identified the user- and transportation characteristics of a P+R user. Previous research on the purpose of using P+R indicates that most users have a work or shopping purpose (Empaction Mobility B.V., 2019; Ortega et al., 2021a). For example, a study on 17 P+R in the Amsterdam Metropolitan Region shows that 67% of the users indicate using the P+R for commuting and 14% for shopping (Empaction Mobility B.V., 2019). The study of Clayton et al. (2014) additionally shows that the highest proportions of travellers were using the P+R for shopping and working purposes, respectively 59% and 20%. The fact that the P+R in the study of Clayton et al. (2014) attracts more shopping travellers instead of commuters could be explained by the fact that the case study was the city of Bath in England, which is an UNESCO World Heritage Site and therefore attracts many tourists. This implies that the purpose of travelling relates to the location of the P+R.

Next to the using purposes, it is studied what factors influence the choice of using a P+R. This relates to the concept of modal choice, which is defined as the decision process of choosing between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors (De Witte et al., 2013). The study of De Witte et al. (2013) defines four types of mode choice factors: (1) socio-demographic indicators, (2) journey-characteristic or trip factor indicators, (3) spatial indicators, and (4) socio-psychological indicators.

Following this typology, the found user- and transportation characteristics are shown in Table 1. The socio-demographic indicators that are key in the travellers' choice of a P+R are income, age and gender. When having different parking fares for city centre parking and for P+R, the study of Clayton et al. (2014) shows that income plays a role in this choice. Age and gender are also mentioned as influential factors in the same study. Regarding the journey-characteristic factors, travel cost is identified most in previous studies, which is the cost of travelling via a P+R (often in monetary terms). For example, the study of Mahmoud et al. (2014) included this factor in a study on P+R usage for cross-regional commuter trips in Toronto, Canada. Huang et al. (2019) mentioned the total travel time with public transport (PTTT) when using a P+R as another trip-related factor, as well as the transfer time switching from private mode to public transport. This influencing factor is also mentioned in the studies of Qin et al. (2012, 2013). Clayton et al. (2014) studied the difference in transportation factors for city centre parking and P+R and mentioned the trip purpose and trip frequency as influence factors. As the last journey-characteristic factor, Olaru et al. (2014) mention the departing time of the user. The spatial indicator mentioned in the study of Olaru et al. (2014) is the quality of the facilities at the P+R. Lastly, Mingardo (2013) describes that the recognition that P+R can reduce environmental pollution also influences the decision to use P+R or not, which is a socio-psychological factor.

Table 1: User- and transportation characteristics influencing P+R usage (categorisation of De Witte et al. (2013)

Category	Factor
Socio-demographic	Income
	Age
	Gender
Journey-characteristic	Public Transport Total Travel Time (PTTT)
	Travel cost
	Transfer time at P+R
	Trip purpose
	Road congestion
	Departing time
	Trip frequency
	Parking fare in city centre
Spatial	Quality of facilities at P+R
Socio-psychological	Environmental awareness

2.2.2 Adverse effects

As described earlier, P+R can be implemented for various policy goals. However, it can also result in adverse effects. Firstly, travellers who used to travel only by public transport now partly drive by car and use a P+R (Mingardo, 2013). Besides, cyclists who used to make the whole trip by bike could now use the P+R instead, so fewer "active" transport kilometres are made (Mingardo, 2013; Zijlstra et al., 2015). Furthermore, P+R could make cities more accessible in general and can lower the generalized cost of travel, so some additional travelling is expected (Mingardo, 2013). In addition, some drivers will use the P+R as a normal parking facility without making use of the public transport connection to the city centre as it might be located close to their final destination (Mingardo, 2013; Zijlstra et al., 2015). Lastly, to reach a P+R users might take a detour, for which in some cases the total vehicle kilometres travelled are even higher than if the user had driven directly to the destination (Zijlstra et al., 2015). These adverse effects are likely to increase the net traffic volume instead of a reduction, as was mentioned in the studies of Parkhurst (2000) and Parkhurst and Richardson (2002).

To cope with the magnitude of these unintended effects, the introduction of a parking fare for the P+R could contribute. Former public transport users and cyclists might use these transportation modes again (Mingardo, 2013). However, this depends on the prices of city parking since that might be more attractive when the P+R is priced. Pricing is, therefore, a useful tool for governments, since P+R could be made cheaper than city centre parking (Kepaptsoglou et al., 2010). In addition, Rongen et al. (2022) mention four key innovations that could further exploit the potential of P+R and reduce the adverse effects, namely shared mobility, mobility as a service (MaaS), vehicle electrification and demand-responsive transit (DRT).

2.3 Shared Micromobility

Shared micromobility is defined as the collaborative utilization of a bike, e-bike, e-moped or other low-speed modes, allowing users to access them on a short-term, on-demand basis (Shaheen et al., 2019). An overview that distinguishes the different types of shared micromobility systems is shown in Figure 4. This section will elaborate on the different systems and the user- and transportation characteristics that influence using shared micromobility.

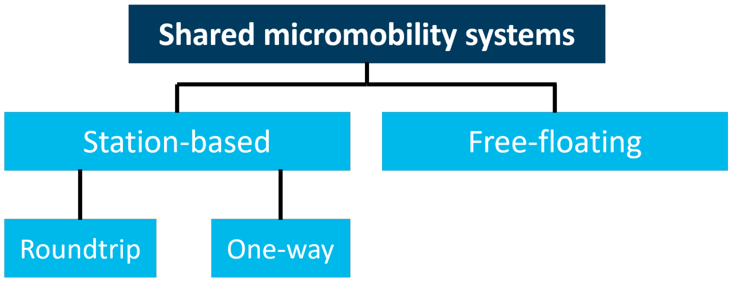


Figure 4: Overview of shared micromobility systems

- **Station-based - Roundtrip:** shared vehicles are located in a fixed place and should also be returned to that place after use (KiM, 2021a). The OV-fiets of NS is a form of a roundtrip station-based system. Currently, almost 80% of the shared bikes are OV-fietsen of the NS. Therefore, the station-based roundtrip system is currently the most common bike-sharing system (KiM, 2021a).
- **Station-based - One-way:** shared vehicles are located in a fixed place and can be returned within a certain area to another fixed location (KiM, 2021a). Examples of this system are the KeoBike or the shared bike of Arriva (Arriva, 2024a).
- **Free-floating:** shared vehicles are spread across a city and users can pick up and leave the shared mode at a random location or a large number of designated locations. In the latter case, providers apply a geofence technology where they designate parking zones in an application in consultation with local authorities. Users who park outside these areas cannot close the (digital) lock, which means that the rental of the shared mode continues (KiM, 2021a). Most shared e-bike and e-moped systems have a free-floating system, like Tier, GO Sharing and Felyx.

2.3.1 User- and Transportation Characteristics

The purpose of travelling with shared modes differs per mode type. Previous research into shared bike usage of Van Marsbergen (2020) and Van Waes et al. (2018) indicates that the purpose of travelling is mostly socio-recreational related. However, a study of Shaheen et al. (2013) in four cities in North America found out that the most common trip purpose was to go to work or school. Finally, the studies into shared e-mopeds indicate that most trips are made to work/school and leisure trips (Laa & Leth, 2020; Sanders et al., 2020).

To identify user- and transportation characteristics that influence the choice for shared micromobility, previous studies are reviewed. An overview of the identified user- and transportation characteristics is shown in Table 2. Of the socio-demographic factors, four of the five factors influence both the choice of shared (e-)bikes and shared e-mopeds. The gender of a user is only found to be an influencing factor for the shared e-moped. Most factors found in previous studies are journey-characteristic related. The travel distance, travel time, travel cost, distance to shared modes, ways of paying, and frequency of use are significant influence factors for the shared micromobility modes. Guo and Zhang (2021) found that if the purpose of travelling with an e-moped is a leisure purpose, this increases the likelihood of using this mode compared to a commuting purpose. The ways of paying are identified as a significant characteristic by Horjus et al. (2022) and mentions that whether users can only pay by app or also via dedicated machines/pillars influences the decision for shared bicycles and e-mopeds. In the study of Garritsen (2022) the transfer time between modes is indicated as a significant factor since shared modes are often used for multimodal trips and the transfer time influences the total travel time. As the last trip-related characteristic, the weather circumstances influence the choice of using a shared bike according to Jonkeren (2020) and van Marsbergen et al. (2022).

As a spatial factor, the quality of the facilities is identified for all shared modes, as the type and amount of facilities near shared modes influence the choice of using a certain mode (Garritsen, 2022; Jahanshahi et al., 2020). Five socio-psychological characteristics are described in previous studies, where four of them are identified by the study of Van Veldhoven et al. (2022). The research describes that if more people are using shared mobility, this socially influences people to also use it. Besides, if people have compatibility with the community and lifestyle of shared modes they are more likely to use it. Finally, this study also addresses that the level of digital skills influences people's decision to use shared modes, which is also described by Garritsen (2022) and Horjus et al. (2022). For the shared bike and e-moped, the experience in using it is mentioned as a significant socio-psychological factor by Horjus et al. (2022).

Table 2: User- and transportation characteristics influencing shared micromobility usage (categorisation of De Witte et al. (2013)

Category	Factor	Shared (e-)bike	Shared e-moped
Socio-demographic	Age	X [1, 4, 5]	X [5, 6, 7]
	Gender		X [3, 6, 7]
	Education	X [1, 4, 5]	X [5, 7, 10]
	Household income	X [2]	X [3]
	Mode ownership	X [2, 9]	X [3, 9]
Journey-characteristic	Travel distance	X [4, 8]	X [7]
	Travel time	X [9]	X [7, 9]
	Travel cost	X [4, 8]	X [7]
	Frequency of using	X [5]	X [5]
	Trip purpose		X [3]
	Ways of paying	X [5]	X [5]
	Transfer time between modes		X [10]
	Distance to shared modes	X [2]	X [10]
	Weather circumstances	X [11, 12]	
Spatial	Quality of facilities	X [14]	X [10]
Socio-psychological	Social influences	X [9]	X [9, 10]
	Perceived compatibility with daily life	X [9]	X [9]
	Experience	X [1, 5]	X [5]
	Environmental awareness	X [9]	X [9]
	Digital skills	X [1, 5, 9]	X [5, 9, 10]

[1]Garritsen et al. (2024), [2]Bachand-Marleau et al. (2012), [3]Guo and Zhang (2021), [4]KiM (2021a), [5]Horjus et al. (2022), [6]Sanders et al. (2020), [7]Christoforou et al. (2021), [8]Ma et al. (2020), [9]Van Veldhoven et al. (2022), [10]Garritsen (2022), [11]Jonkeren (2020), [12]van Marsbergen et al. (2022), [13]Fleury et al. (2017), [14]Jahanshahi et al. (2020)

2.4 Accessibility evaluation

The concepts of mobility hubs and P+R are closely related to the theory of land use and transport interactions (LUTI), which implies that land use factors influence the demand for multimodal travel (van Wee, 2011). Accessibility is also an important concept in LUTI studies and is defined as the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s) (Geurs & van Wee, 2004). This section will discuss how accessibility can be evaluated. It reflects on the different accessibility measures and how accessibility measures are applied in studies about P+R locations, mobility hubs and shared mobility.

Four perspectives on measuring accessibility are described in the research of Geurs and van Wee (2004):

- **Person-based accessibility measures** assess accessibility at the individual level, e.g. the activities an individual can engage in at a given time (Geurs, 2018).
- **Utility-based accessibility measures** come forward from economic studies and analyse the (economic) benefits that people derive from access to spatially distributed activities (Geurs & van Wee, 2004).
- **Infrastructure-based accessibility measures** describe the performance of the network in terms of congestion, travel time and cost. An example of such a measure is network centrality, which is used to identify critical nodes within social, economic, and physical networks (Geurs & van Wee, 2004).
- **Location-based accessibility measures** describe the level of accessibility to spatially distributed activities, such as the number of amenities within a 20-minute travel time from origin locations. These types of measures are typically used in urban planning and geographical studies (Geurs & van Wee, 2004).

Multiple studies have conducted accessibility evaluations focusing on P+R locations, mobility hubs and shared mobility, using various accessibility measures. In the study of Ortega et al. (2021a), a model is developed that considers trips in different traffic conditions from P+R locations to display the dynamic accessibility in different areas. This is an example of an infrastructure-based measure, as it considers infrastructure-related aspects such as congestion. The study shows that the accessibility of a P+R system varies depending on the traffic volume. A location-based approach is applied in the research of Ortega et al. (2020), where the demand for P+R facilities is analysed using different methods for example the market area method for which the number of facilities for a time threshold is determined.

A comparable location-based accessibility measure is also used in the manual of UUM (2023). This manual discusses how mobility hubs score on the different dimensions of the SmartHubs Integration Ladder (Geurs et al., 2023), which is discussed in section 2.1, and where there are still opportunities for improvement. A cumulative opportunities measure is applied that counts the number of jobs that can be reached within a given time budget and cost budget.

Regarding the accessibility of shared modes, a study of Capodici et al. (2021) looked into the accessibility of cycling and rail transport services and how multimodality between (shared) bicycle and rail transport systems could be assessed. Given bike infrastructure data and data of public transit stops, catchment areas could be generated and workplaces reachable given a time threshold are determined. The research shows that multimodal transport can be an effective way to stimulate sustainable mobility in cities and efficiently connect suburbs with low-frequent public transport services to the main public transport nodes. The research of Abouelela et al. (2024) focused on shared (e-)scooters and proposes a framework to evaluate shared (e-)scooter equity based on accessibility or lack of accessibility to different activities compared to other existing modes of transportation. To assess the accessibility to the different opportunities, the geographical location of points of interest (POI) was used. A more infrastructure-based measure was used in the research of Liu et al. (2021) that assesses the accessibility of dockless shared bikes from a network perspective, considering bicycle travel characteristics such as travel time and travel speeds. The results of the research suggest that central districts have a higher shared bike accessibility compared to peripheral, suburban regions.

2.5 Research Gap

As this research focuses on the potential of shared micromobility at P+R, the academic database of Scopus was consulted combining the keywords “shared mobility” and “Park and Ride”, to look for previous studies. In total 4 studies were found that relate to these terms, of which three focus on the potential of autonomous vehicles in combination with a P+R. The studies of Gurumurthy et al. (2020) and Twumasi-Boakye et al. (2021) focus on the effect of shared autonomous vehicles on public transit use when providing this at a P+R, by doing a simulation-based study. Zhou et al. (2023) applied agent-based simulation in a study focusing on the opportunities of exploiting private automatic electric vehicles as last-mile feeder service to commuters during idle time when parked at P+R. The last identified research is a paper by Rongen et al. (2022), that analysed the mobility hub concept in the Netherlands and mentioned shared mobility as a potential innovation for current P+R. Other keywords such as “shared bike”, “shared car” and “shared e-moped” in combination with “park and ride” did not result in (additional) search results. In addition, the discussed literature by the studies of Geurs et al. (2023) and Roukouni and Correia (2020) are reviewed and used in this literature review when found applicable. However, no previous studies were found that specifically investigated the potential of shared mobility at P+R.

Nevertheless, there are previous studies that interface with this study and focus on the intentional behaviour of people to use shared micromobility. As part of the SmartHubs project, deliverable 5.1 focuses on the impacts of mobility hubs on mobility patterns and behavioural change (Gkavra et al., 2024) and for deliverable 5.3 an equity assessment was conducted and focuses on the potential impact of mobility hubs on six vulnerable-to-exclusion (V2E) groups (Garritsen et al., 2024). Furthermore, the master thesis of Garritsen (2022) studied the physical and digital integration factors that influence potential users’ intention to use e-mopeds at mobility hubs, and in the study of Van Veldhoven et al. (2022) key factors that influence adoption intentions of shared mobility are identified. In addition, research of Horjus et al. (2022) investigates the intention to use shared modes and public transport in a multimodal transport network and the factors and user characteristics that affect this intention. For all the above-mentioned studies, a survey was used to identify the relevant user- and transportation characteristics of shared mobility users.

As no previous research studied the user- and transportation characteristics of P+R users towards shared mobility, this research might be able to identify these factors. This helps to further substantiate the potential of shared micromobility at P+R, as described by Kwantes and Scheltes (2021) and Rongen et al. (2022). Besides, an accessibility analysis that compares public transport with shared mobility can also visualize the effect of adding shared mobility at a P+R on the accessibility of an area.

2.5.1 Conceptual Framework

The problem context described in this research will focus on the potential of shared micromobility at existing P+R locations. The information from the literature review can be used to conduct this research, which is illustrated in the conceptual framework shown in Figure 5. Each part of the figure will shortly be explained below the figure.

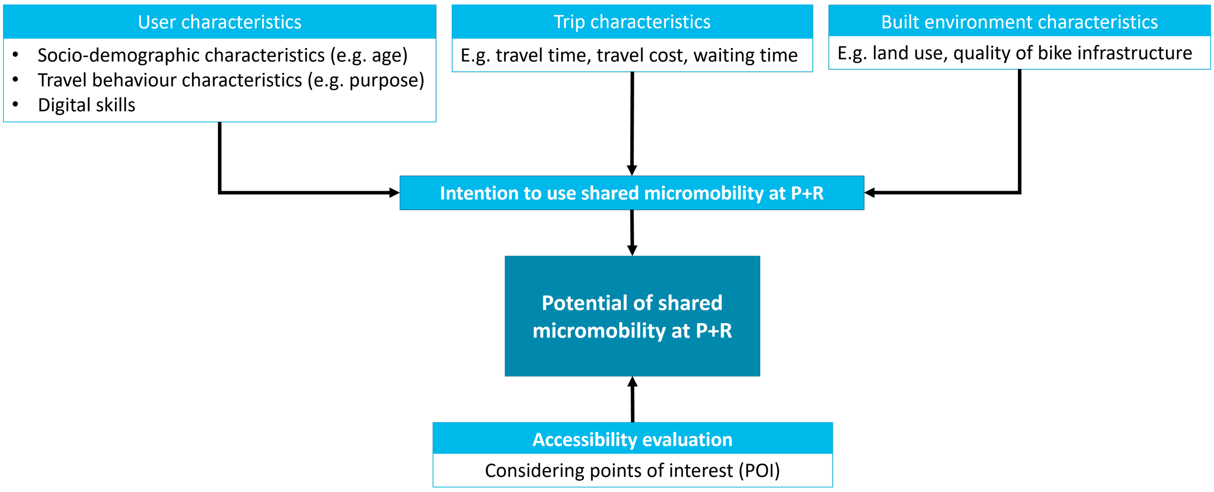


Figure 5: Conceptual framework to study the potential of shared micromobility at a P+R location

A major part of this research will focus on the characteristics that influence the intention of P+R users to use shared micromobility. The classification of a study of De Witte et al. (2013) was used in section 2.2 and section 2.3 to categorise the user- and transportation characteristics found in the literature that influence P+R use and shared mode use respectively. In this framework, three types of characteristics that influence the intention to use shared micromobility at a P+R location are defined:

- **User characteristics** include socio-demographic characteristics such as age and gender, which help to characterize the survey respondents. Besides, it contains travel behaviour characteristics such as the frequency of use and trip purpose since they were mentioned as influential factors in Table 1 and Table 2. Finally, the digital skills of a respondent are considered as user characteristic.
- **Trip characteristics** include factors that can be linked to the transport mode or the trip itself, such as travel time and travel cost. As shown in Table 2, these characteristics are mentioned to influence the intention to use shared micromobility in previous studies and are therefore included in this framework.
- **Built environment characteristics** include factors that describe the spatial context where the trip and mode choice takes place, and can influence the intention to choose for shared micromobility or not as a last-mile transportation mode. Multiple previous studies have studied what built environment characteristics influence the mode choice, focusing particularly on active modes. A bikeability index was developed in the research of Hartanto (2017) that describes the quality of cycling in a specific area. Furthermore, the study of Meng et al. (2016) found that the land use type (i.e. residential, commercial or industrial) influenced the choice of transport mode. The study of Winters et al. (2010) considered the degree of urbanisation as a built environment characteristic in its study to determine the likelihood of cycling.

A selection of characteristics relating to these three categories will be used to analyse how they influence the intention to use shared micromobility at a P+R location, by conducting a survey study. Which characteristics are included in this study, will later be discussed in this report.

Section 2.4 showed that in various studies related to P+R locations, mobility hubs or shared mobility an evaluation of the accessibility was conducted. It is expected that this also contributes to the focus of this research, therefore it is part of the conceptual framework shown in Figure 5. To express the accessibility, a location-based accessibility measure will be used and points of interest (POI) will be considered to express the accessibility. The precise method of the accessibility analysis will later be discussed in this report.

3 Research Aim & Questions

This chapter consists of two parts. First, the scope of this research will be clarified describing the boundaries and focus of this research. Then, the research aim and questions related to that aim are presented.

3.1 Scope

Section 2.2 introduced two types of P+R locations: remote P+R and peripheral P+R locations. This research only considers peripheral P+R locations, which aim to intercept car traffic heading towards the urban centre and are usually located at the edge of a city (Rongen et al., 2022). As described in the problem context, the development of P+R locations to transfer hubs with shared mobility and other facilities could increase the use of P+R locations and so contribute to the improvement of the liveability in low-traffic areas (KiM, 2021b; Kwantes & Scheltes, 2021; Rongen et al., 2022). Since shared mobility is currently mostly provided in urban areas and is more used for last-mile trips compared to first-mile trips (CROW, 2024b), it is chosen to only focus on peripheral P+R locations and thus the potential of shared micromobility as last-mile mode.

Two P+R locations are considered to function as study areas. The locations are selected as part of a research question. To conduct the research within the set research period, distributing the survey at two locations was seen as achievable.

Since this study focuses on the last mile travel from a peripheral P+R to a destination location, only shared micromobility types are considered. Three shared modes are considered for this research: the shared bike, shared e-bike and shared e-moped. Shared cars are excluded as a shared mode in this study, as people already arrive with a private car. This makes it highly unlikely that P+R users will transfer to a shared car.

3.2 Research questions

This research aims to analyse the potential of shared micromobility at peripheral Park and Ride locations in the Netherlands. The focus is on investigating current last-mile transportation options, and the intention to use shared micromobility. In addition, an analysis of accessibility to points of interest (POIs) by shared modes and public transport is undertaken to quantify the potential of these modes. To achieve the research objective, the following research questions are formulated:

1. What are the characteristics of peripheral P+R locations in terms of location, public transport network and presence of shared mobility?
2. What are the characteristics of P+R users at the studied locations?
3. What factors influence people's intention to use shared mobility as a last-mile transportation mode at a P+R location?
4. What is the difference in accessibility between shared mobility and public transport as last-mile transportation modes at a P+R location, considering cost and time thresholds?

4 Methodology

This chapter will elaborate on the methodology of this research. This is done in four sections. An overview of the methodology is presented in Figure 6.

Section 4.1 discusses the method for the spatial analysis of peripheral P+R locations in the Netherlands. For this spatial analysis, characteristics of peripheral P+R locations in the Netherlands are analysed in terms of location, public transport network and presence of shared mobility. The gathered information is used to conduct a multi-criteria analysis (MCA) so that suitable P+R locations for this study can be selected. With the execution of the spatial analysis, the first research question can be answered.

To answer the second and third research questions, a survey was developed that was distributed at the selected study locations. Section 4.2 discusses the set-up of the survey, covering the different characteristics of P+R users questioned. Additionally, the distribution process of the survey is discussed in this section. The descriptive statistics of the characteristics are analysed to answer the second research question.

The method for answering the third research question is covered in section 4.3. A regression analysis is conducted to determine factors that significantly influence the intention of using shared micromobility at a P+R location. Before executing the regression analysis, the data is prepared and the assumptions of the regression analysis are tested. Then the regression analysis is conducted, after which hypotheses are assessed. This methodology section presents the hypotheses, which are based on previous studies discussed in the literature review, and elaborates on the applied regression model and assumptions that are tested before the regression is conducted.

The last part of the methodology consists of an accessibility analysis which is conducted to analyse the difference in accessibility between shared micromobility and public transport at the selected study location. Section 4.4 discusses which accessibility measure is used, and how accessibility is expressed. The results of the accessibility analysis are used to answer the fourth research question.

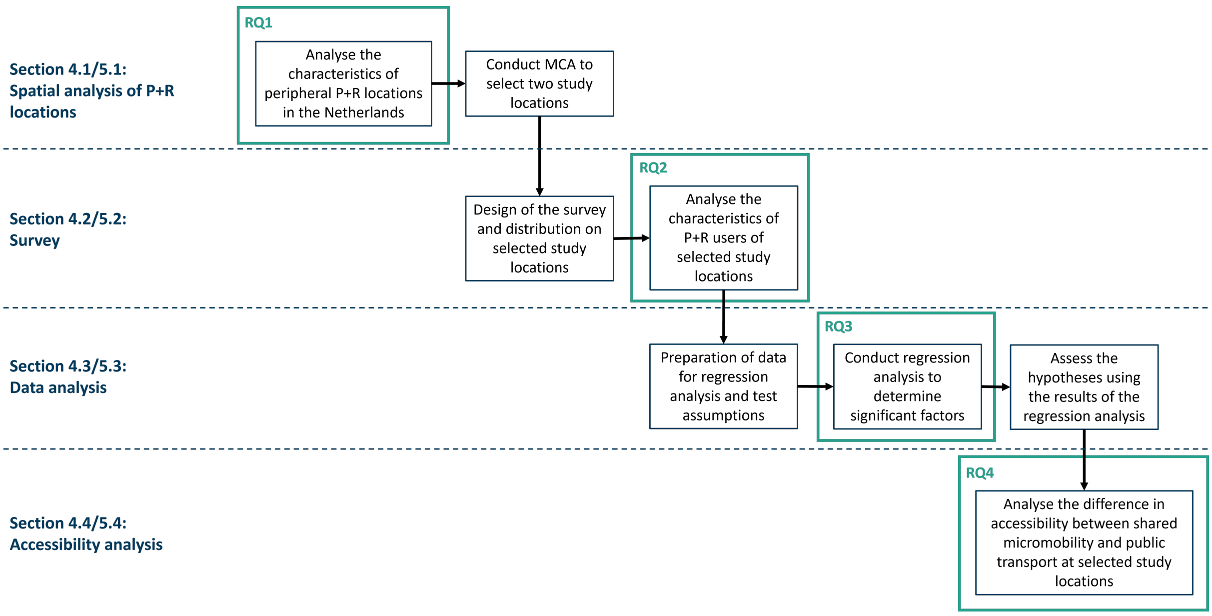


Figure 6: Overview of methodology. The green frames indicate to which research question some steps belong.

4.1 Spatial Analysis P+R locations

The first step of the methodology is a spatial analysis of peripheral P+R locations in the Netherlands. This analysis provides an overview of the peripheral P+R locations and how they are currently located and developed. Several data sources are used to analyse transportation- and location-related characteristics of the P+R, to answer the first research question. Besides, the information on peripheral P+R locations is used to conduct a multi-criteria analysis (MCA) so that P+R locations suitable for this study can be selected.

As described in section 3.1, the shared car is not considered as a last-mile transportation mode in this study. For the spatial analysis, shared cars are included to provide a complete overview of the availability of shared mobility at peripheral P+R locations. In the multi-criteria analysis, only attributes related to shared micromobility are considered.

4.1.1 P+R Attributes

Various data sources are used to obtain information from the peripheral P+R in the Netherlands. Table 3 shows the attributes and the source(s). These attributes are considered as they are needed to conduct the MCA. Below the table, each attribute will shortly be discussed.

Table 3: Attributes and sources for spatial analysis of peripheral P+R locations

Attribute	Source
P+R locations	SHPV and NDW (2024)
Public transport modes	OpenOV (2023) and REISinformatiegroep BV (2024)
Public transport frequency	REISinformatiegroep BV (2024)
Shared mobility availability	CROW (2024a), Greenwheels (2024), MyWheels (2024), and NS (2024a)
Distance from national/regional roads	Google (2024)
Distance to city centre	Google (2024)
Travel time public transport	REISinformatiegroep BV (2024)
Travel time shared micromobility	Google (2024)

P+R locations

The dataset of SHPV and NDW (2024) consists of data from off-street car parks and lots, on-street parking spaces, and provides information on the GPS coordinates. The data also includes P+R locations selected from the dataset based on their name. Locations that include P+R or Transferium (or something similar) in the name were selected, which resulted in 434 parking locations. These locations were stored in a separate shapefile for further analysis. Each P+R location in the dataset was checked on location and presence, using Google (2024) and the station information of NS (2024b). It was found that some locations were double or wrong-located, and therefore not included.

As described in section 2.2 of the literature review, there are two main types of P+R: remote P+R and peripheral P+R. This research focuses only on peripheral P+R for which public transport services are used to cover the last kilometres, often located at the edge of a city. However, the dataset does not include a distinction for the two types of P+R. Therefore, a type was assigned by the researcher to each P+R location. Peripheral P+R aim to intercept car traffic heading towards the urban centre and is usually located at the edge of a city (Rongen et al., 2022). To intercept car traffic, municipalities of the cities inform travellers via their website about P+R locations that they can use. It was therefore decided to categorize P+R as peripheral P+R when a municipality of a (large) city mentions the location as an option to enter the city on their website. Checking the websites, it was found that four locations were missing in the dataset. These have been entered manually. All other P+R locations were categorized as remote

P+R. It was found that these locations are mostly located next to a train station.

As this study only focuses on peripheral P+R, the next attributes are only obtained for this type of P+R location.

Public transport modes
For each peripheral P+R location, the available public transport modes for the travellers' last mile are assessed. Since peripheral P+R are designed to intercept car traffic to the city centre (Rongen et al., 2022; Zijlstra et al., 2015), the dataset of OpenOV (2023) is checked to see which public transport connections link the P+R with the city centre. The following categories are defined and assigned: Bus, Tram, Metro, Train or Multiple public modes.

Public transport frequency
Next to the type of public transport, also the frequency of the connection(s) was considered for each location. To determine the frequency, the route is planned with the 9292 journey planner (REISinformatiegroep BV, 2024) with as destination the central station of the city of interest. The central station was chosen as the destination location since it is often located close to the city centre and most public transport connections travel via or towards the station. As the frequency can vary during the day and between days, a Thursday between 08.00h and 09.00h is chosen as the date and time. Most people are expected to travel via a P+R during the morning peak on weekdays, so the frequencies are based on this moment. The following bins are chosen to indicate the frequency of public transport connection: 1-5 min, 6-10 min, 11-15 min, 16-20 min and > 20 min.

Shared mobility availability
For all analysed P+R locations, public transport is always an option as a last-mile connection. At some locations shared modes are also available. For each P+R location is checked if any form of shared mobility is present, and if so what modes. As there is currently no single database that provides a complete overview of all shared modes, several sources were consulted. The main provider of *shared bikes* is the NS with OV-fiets. The locations where these shared bikes are available can be obtained from their website (NS, 2024a). OV-fiets is a station-based roundtrip system, which means that the bike needs to be returned to the same location from where it was picked up. People pay one fee for 24-hour usage. Next to OV-fiets, Deelfiets Nederland (2024) and Arriva (2024a) also provide shared bikes at multiple locations in the Netherlands. Finally, the websites of various municipalities are checked to see if shared bikes are provided by the municipalities at P+R locations.

Various companies provide *shared e-bikes* and *shared e-mopeds* in the Netherlands. The shared mobility dashboard of the CROW (2024a) provides an overview of the real-time location for all shared e-bikes and e-mopeds of various service providers. The dashboard was checked on 10 January 2024, but since this is real-time data, shared modes might not always be present at the P+R locations. Nevertheless, if shared modes are indicated to be present, the P+R lies within the service area indicated by the provider. These shared modes are a free-floating system, which means that the e-bikes and e-mopeds are distributed at random locations in the city and do not have to be returned at a fixed location.

As no location data was available of *shared cars* on the shared mobility dashboard, the locations were obtained from the websites of Greenwheels (2024) and MyWheels (2024). These service providers are known as two of the largest providers of shared cars (Bright & RTL Nieuws, 2022).

Distance from national/regional roads
A P+R location is ideally located close to the main road network, so the possible extra travel time people spend when using a P+R instead of directly driving to their destination is limited (VenhoevenCS & Rijkswaterstaat, 2020). Therefore the distance from national or regional roads to the P+R are checked. The distance between the closest national/regional road and the P+R is determined with Google Maps (Google, 2024), taking the beginning of the off-ramp as the origin and the P+R as the destination and planning the route for a car.

Distance to city centre
The distance from the P+R to the city centre is also included as an attribute, as this distance influences the range of last-mile transportation modes that are interesting alternatives to public transport. When planning the route via Google Maps (Google, 2024), the route and distance differ for the mode options. The distance to the city centre is based on the route for cyclists, as it is unlikely that people continue their journey with a car, after parking at a P+R. It is assumed that the destination for most P+R users is the city centre, therefore the destination is a location in the city centre. To determine the route, the destination location is generated by Google Maps indicating, for example, "Binnenstad Den Haag" or "Centrum Den Haag" as the destination.

Travel time public transport
The travel time of public transport depends on both the type of public transport and the travel distance to the (central) station. Therefore, it is an interesting attribute to compare with the travel time for shared modes. From the 9292 journey planner (REISinformatiegroep BV, 2024), the travel time for public transport is obtained, with the central station as the destination. For some P+R locations, there are multiple public transport connections to the city centre. Therefore, only the quickest connection with the least amount of transfers is chosen, as that is the most likely route travellers will take.

Travel time shared micromobility
The travel time from the P+R to the city centre is determined for three shared micromobility types: bike, e-bike and e-moped. The travel time for bikes is obtained from Google Maps (Google, 2024), considering the same destination and route as used to determine the travel distance. The average speed of an e-bike and e-moped are higher compared to the average speed using a normal bike, so travel time is expected to be shorter. Therefore, the following average speeds per mode are used to translate the travel time by bike:

- **Average speed shared bike:** 13 km/h (Dozza & Werneke, 2014)
- **Average speed shared e-bike:** 17 km/h (Schleinitz et al., 2017)
- **Average speed shared e-moped:** 19 km/h (Movares, 2023)

4.1.2 Study Area

The attribute information of the P+R locations is used to determine suitable locations as study areas for this research. Three selection criteria are set:

- Only P+R locations with shared micromobility available will be considered, so the intention of current shared micromobility users at P+R locations can be analysed.
- Only P+R locations with a public transport stop and shared micromobility within 200 meters of the parking facilities are considered. This distance is indicated as the desired walking distance to shared modes in the study of Natuur & Milieu (2020).
- The P+R location should be within 4 kilometres of the city centre. Previous research on shared micromobility indicates that shared modes are mainly used for short-distance trips, so it is assumed that trips made with shared modes are unlikely above this limit.

As mentioned above, the last criterion stems from previous research. A report of the KiM (2020a) describes that the average travel distance for shared bicycles is approximately 2.1 km (KiM, 2020a). As a reference, the average travel distance with a normal (private) bicycle is on average 3.3 km. In addition, the median travel distance of "OV-fietsen" is found to be 3 kilometres (Pluister, 2022). For shared e-bikes, research indicates that most trips are conducted between 1 and 3 kilometres (Guidon et al., 2019). Lastly, for shared e-mopeds, previous research describes that the average travel distance is 3.5 kilometres (Movares, 2023). The relatively short travel distance by shared mobility results from the service areas where these modes are provided, namely in urban areas where the travel distances to utilities are relatively short. In addition, in the case of free-floating vehicles, people pay per minute. This means that only short trips are beneficial.

Multi-criteria analysis

A multi-criteria analysis (MCA) is conducted to balance the attributes and find the most suitable locations for this research. For the considered attributes, each P+R location gets a rating. This rating has three levels, ranging from "+" as the highest to "-" as the lowest score, with "o" as the score in between. The attributes are rated on the following aspects:

- The **distance from national or regional roads** to the P+R location. The closer a P+R is located to a national or regional road, the higher the score, as these P+R locations are likely to be better used (CROW, 2005; VenhoevenCS & Rijkswaterstaat, 2020). Selecting a well-occupied P+R location is important to get a sufficient response to the survey.
- The available **public transport modes and frequency** as they are related and influence the usage of the P+R location. A P+R location with no frequent public transport connection is less likely to be used, as the total travel time when travelling via the P+R increases due to waiting times. On the other hand, a P+R location with multiple public transport connections running very frequently (e.g. every 5 minutes) might be well-used, but shared mobility has less added value as travel times with shared modes are often larger compared to public transport. It is therefore assumed that the current shared mobility usage is limited at these locations. To select a well-used P+R where shared mobility is likely to be used, P+R locations with a frequency of every 11 to 20 minutes have the most potential. Whereas locations with multiple public transport connections and a high frequency or locations with a frequency greater than 20 minutes score low.
- The available **shared micromobility** and type of service as an estimation of how shared micromobility is currently used at the P+R locations. P+R locations with good shared mobility conditions are also preferred to measure the behavioural intention of current shared micromobility users. A P+R location with a station-based roundtrip system is the most reliable in supply (often OV-fiets) and is therefore rated with the highest score. Locations with only one type of free-floating shared mode are less reliable and get the lowest score, as it is less likely that people are currently using shared micromobility at these P+R locations.
- The **travel time of public transport and shared micromobility** for comparison. P+R locations for which shared modes have a lower travel time compared to public transport, get the best score as this makes shared mobility attractive to use. In contrast, locations where the public transport connection is faster and/or has a high frequency have less potential for shared micromobility.

After assessing each P+R location for the mentioned attributes, a ranking can be made for the suitability of the P+R locations for this research. Information on the occupancy rate (if publicly available) and parking places are added, as this might also provide some insight into the current P+R usage.

4.2 Survey

A survey is developed to answer the remaining research questions. The aim of the survey is twofold. On the one hand, it aims to give insight into the user characteristics and attitudes towards last-mile transportation modes of the P+R users. On the other hand, it aims to identify factors that significantly influence the use of shared micromobility at a P+R as a last-mile transportation mode. This provides insight into the potential of shared micromobility when public transport is already present.

The survey is distributed among users of P+R Maastricht Noord and P+R Deutersestraat. These P+R locations are selected by a multi-criteria analysis as described in the previous section. Surveying this target group can give insight into the current usage of the P+R and which factors are valued as important. For three weeks, the survey has been distributed among the two P+R locations. A flyer with a QR code was handed out by the researcher. The survey was only available in Dutch. The flyer can be found in Appendix A.

At P+R Maastricht Noord, the researcher distributed flyers from March 11th to March 15th. During this period, 312 flyers were handed out. In addition, the Zuid-Limburg Bereikbaar programme office distributed the survey online through an article on the website of Maastricht Bereikbaar (2024), and in the newsletter which was received by 17,019 people. The survey was also sent to the mobility panel of Zuid-Limburg Bereikbaar consisting of around 4,500 people living in the province of Limburg. For P+R Deutersestraat, the flyers were distributed for 8 days in the period between March 16th and March 28th. During this period, 548 flyers were handed out among the P+R users of this location.

During the development, the survey was tested in two rounds. In the first feedback round, the graduation committee of the thesis project consisting of three members assessed the survey. After implementing the feedback, the survey was tested by 34 people consisting of the external and daily supervisor of the thesis project, 12 employees from Royal HaskoningDHV and 20 friends or family members.

4.2.1 Set-up

The developed survey is based on a review of questionnaires from previous studies related to travel behaviour, shared mobility or mobility hub usage (Gkavra et al., 2024; Horjus et al., 2022; Jahanshahi et al., 2020; Knijnenburg, 2023; Rijsman et al., 2023). The complete survey can be found in Appendix B. It consists of the following parts:

- A. Travel behaviour
  - A1. General travel behaviour
  - A2. P+R travel behaviour
- B. Trip characteristics related to mode choice
- C. Socio-demographic information
- D. Digital skills

Part A of the survey consists of questions related to the travel behaviour of the respondents. It is split up into two parts. First, the P+R users are questioned on their general travel behaviour. Users are asked how often they have used public transport and shared mobility in the past year. Besides, their physical ability to walk, cycle and scooter are questioned. The questions in the second part focus on the last-mile trips from the P+R location to the destination of the respondents. It includes questions on the current transport mode people use, their motivation for using that mode and purpose of travelling, and their intention towards other last-mile transportation modes. For each of these questions, people have to consider the most recent trip they made from the P+R to their destination.

Part B of the survey focuses on the importance of trip characteristics related to mode choice. For eight characteristics, respondents are questioned how important they find the characteristics when travelling from the P+R to their destination, for example, the travel time or waiting time at the P+R. A 5-point Likert scale ranging from hardly important to very important is used to rate the trip characteristics.

Part C of the questionnaire includes questions on the socio-demographic information of users, for example, age and education level. The information of the users can be used to explain the behavioural intention of respondents.

Part D of the survey consists of questions relating to the digital skill levels of the respondents. As described by Horjus et al. (2022), the digital skills of a respondent relate to the components of information/planning and payments on a smartphone. Therefore, higher digital skills explain a higher intention to use shared transport. The study of Horjus et al. (2022) defined the following digital skill categories:

- Level 0: no access to a mobile phone.
- Level 1: access to a mobile phone, but no trip planning activities via an app are performed.
- Level 2: access to a mobile phone and using the phone to plan a trip, often using an app.
- Level 3: access to a mobile phone and using the phone to both plan a trip and do payment and/or reserve related activities via an app.

For this study, level 3 is split up into two groups. A distinction is made between people who use applications to buy tickets/reserve seats for public transport or use applications for shared mobility (Level 3B) and people who are only experienced with applications to transfer money or do online shopping (Level 3A). A difference between people who have digital skills level 3B, and people who do these digital actions is expected, therefore this distinction is made.

4.3 Data Analysis

The third section of this methodology chapter encompasses the data analysis conducted to answer the third research question. Based on the literature, hypotheses are drawn up and will be discussed in the first paragraph of this section. The hypotheses will be assessed based on the outcome of the regression analysis. Next to the hypotheses, this paragraph presents an overview of the variables considered in the regression analysis. The regression analysis aims to identify factors that significantly influence the intention to use shared micromobility at a P+R location. The second paragraph of this section describes the chosen regression model and the assumptions that need to be met.

4.3.1 Hypotheses

The conceptual framework presented in Figure 5 of section 2.5 introduced three categories of characteristics included in this study: user characteristics, trip characteristics and built environment characteristics. Per category, hypotheses are drawn up based on the literature presented in the literature review of this report. After the hypotheses are discussed, an overview of the considered variables for the regression analysis is presented.

User characteristics
Socio-demographic characteristics are the first type of user characteristics to be considered. These characteristics are important as they help to characterize the survey respondents. Besides, they are used to check the representativeness of the survey sample with a population group. For this study, the representativeness is checked by comparing it to a sample from the Onderweg in Nederland (ODiN) dataset, to check if the chosen socio-demographic variables and answer options are in line with the ODiN-data (CBS, 2023b).

Previous studies on the characteristics of shared mobility users show that shared mobility is particularly used by men, younger age groups and highly educated people (Horjus et al., 2022; KiM, 2021a; Shaheen et al., 2016). Looking at our group of respondents, the P+R users, previous research found that the P+R is often used by older age groups (45+) (Clayton et al., 2014). It is therefore interesting to assess the following hypothesis in this study:

> ***H1:*** *The intention to use shared micromobility for last-mile trips from a P+R is higher among male, younger-aged and highly educated P+R users.*

Secondly, the travel behaviour characteristics are considered as user characteristics. Previous research describes that having experience in using shared mobility influences the intention of using it (Horjus et al., 2022). Also, the frequency of public transport usage is found as a significant variable (Horjus et al., 2022). No relation between the frequency of P+R usage and mode choice was found in the literature, probably because at most P+R locations there is only one last-mile transportation option (i.e. public transport). As frequent P+R users are familiar with the P+R location itself and maybe also the surrounding area, you could argue that this group has a higher intention to use shared mobility compared to less frequent P+R users. Next, the trip purpose was found to play a role in the mode choice in the research of Guo and Zhang (2021). It was found that travellers with a leisure purpose have a higher likelihood of using shared mobility compared to travellers with a commuting purpose. Finally, it was found that single-person households or households without children have a higher intention to use shared cars in the research of KiM (2021a). Therefore, it is assessed if there is a relationship between the travel company and the intention to use shared mobility at a P+R location.
The following hypotheses are drawn up related to these travel behaviour characteristics:

> ***H2:*** *The intention to use shared micromobility for last-mile trips from a P+R is higher among P+R users with shared mobility experience.*
>
> ***H3:*** *Frequent public transport users have a higher intention of using shared micromobility for last-mile trips from a P+R compared to non-frequent public transport users.*
>
> ***H4:*** *Frequent P+R users have a higher intention of using shared micromobility for last-mile trips from a P+R compared to less frequent P+R users.*
>
> ***H5:*** *P+R users with a working purpose have a lower intention of using shared micromobility for last-mile trips from a P+R compared to people with a leisure purpose.*
>
> ***H6:*** *P+R users travelling alone have a higher intention of using shared micromobility for last-mile trips from a P+R compared to P+R users that travel with others.*

The final user characteristics category encompasses digital skills. Previous studies about these digital skills indicate that a low digital skill level might be a barrier to use shared mobility (Horjus et al., 2022; Van Veldhoven et al., 2022). Therefore, the following hypothesis is drawn up:

> ***H7:*** *P+R users with a higher digital skill level have a higher intention of using shared micromobility for last-mile trips from a P+R.*

Trip characteristics

The next category contains the factors related to trip characteristics. A selection of the trip factors that were found to influence the intention of using shared mobility as mentioned in Table 2 are considered in the regression analysis. As described in section 4.2, for each trip characteristic respondents are questioned on how important they value the characteristic when choosing a last-mile transportation mode at the P+R. Previous research by Garritsen (2022) and Horjus et al. (2022) show that the significant important trip characteristics for the intended use of a shared mode differ for each mode. Therefore, the following hypothesis is drawn up:

> ***H8:*** *The significantly important trip characteristics for the intended use of shared micromobility differ per shared mode.*

Built environment characteristics

The final category contains the built environment characteristics, which describe the spatial context in which the trip and, consequently, modal choice takes place (De Witte et al., 2013). As it is unknown where the users from the P+R locations comes from, it is not possible to consider the built environment characteristics that describe the population at the origin locations, which might influence the choice for using the P+R. Besides, the origin of the last-mile trip is the same for every user in the survey sample, namely P+R Maastricht Noord or P+R Deutersestraat. The information about the destinations of the P+R users and the chosen transport mode makes it possible to assume a route, most likely the shortest path route. It is therefore possible to study how built environment characteristics of the route could influence the intention of using shared micromobility.

Previous research considering built environment factors along a route or in an area studied for example the type of land use (Koch & Dugundji, 2021; Meng et al., 2016), considered the degree of urbanisation (Winters et al., 2010), or focused on the bicycle infrastructure as that is mostly used by shared modes (Lu et al., 2019; Mertens et al., 2016; Shen et al., 2018). For this research, the bicycle infrastructure quality is considered as a built environment factor. Having the destinations of the respondents and a dataset from the Fietsersbond (2022), a bikeability index can be determined per respondent. The applied method is based on previous research of Hartanto (2017) that developed a bikeability index for assessing transit-oriented nodes in an area. Instead of calculating the bikeability index for different areas around nodes, an index is calculated per route. Four bike infrastructure characteristics from the Fietsersbond data are considered, namely the type of road (e.g. solitary bike path or normal road), the road surface (e.g. asphalt or tiles), the road quality (expressed in levels bad, reasonable and good), and the road lighting (expressed in levels no light, limited light and good light).

Combining the different characteristics of the bike infrastructure, the route can be assessed, and an index can be calculated. The method that describes the exact determination of the bikeability index is explained in Appendix D. Regarding this index, the following hypothesis is drawn up:

> ***H9:*** *The quality of the bike infrastructure affects the intention of using shared micromobility for last-mile trips from a P+R.*

Overview of variables

Table 4 presents an overview of the variables that are included in the regression model. The left column presents the independent variables. These variables are analysed in the regression analysis to assess whether there is a significant relation between them and the dependent variables in the right column. For some of the included variables, no hypothesis is drawn up, as they were not found to be significant predictors in previous studies. They are included in the model, as there could be a significant relation.

Table 4: Overview of variables that are analysed in this research

Independent variables		**Dependent variables**
User characteristics	Trip characteristics	Intention to use shared bike
Gender	Travel time	Intention to use shared e-bike
Age	Travel costs	Intention to use shared e-moped
Education level	Payment methods at P+R	
Occupation status	Availability of transport mode	
Migration background	Ease of use transport mode	
Walking difficulty	Waiting time at P+R	
Ability to use e-moped*	Distance to parking place	
	Facilities at P+R location	
Shared mobility experience		
Frequency of public transport usage	Built-environment characteristics	
Frequency of P+R usage	Bikeability index	
Trip purpose	Distance to destination	
Travel company (alone/with others)		
Digital skills level		

* Only included in the regression model for the intention to use a shared e-moped

4.3.2 Regression Analysis

A major part of this study's result is derived from a regression analysis. This analysis aims to determine the influence of independent variables of user characteristics and trip-specific factors on the dependent variables of the intention to use shared micromobility at the P+R locations. A regression analysis is a statistical method used to analyse variables that might influence an objective and to determine important factors or those that can be ignored (Qualtrics, 2023). Four main categories of regression analysis are known, varying on the type and number of variables included in the analysis. For this study, a logistic regression model is applied, that models the probability of a discrete outcome based on the influence of independent variables (Qualtrics, 2023). There are three types of logistic regression models: binary, multinomial and ordinal logistic regression. An ordinal logistic regression model is applied, as our dependent variables have five outcomes and the outcomes are in a defined order (varying from very unlikely to very likely) (IBM, 2023b). Multiple previous studies into the intended use of shared micromobility also used an ordinal logistic regression model (Garritsen, 2022; Garritsen et al., 2024; Horjus et al., 2022).

For applying an ordinal logistic regression model, four assumptions need to be tested (Laerd Statistics, 2018):

1. The dependent variable should be measured on an ordinal level. This assumption is met since a 5-point Likert scale is applied for measuring the dependent variables.
2. The independent variables are either continuous, categorical or ordinal. The variables resulting from the survey are all continuous, categorical or ordinal, and the distance and bikeability index are both continuous variables. Therefore, this assumption is also met.
3. There is no multicollinearity. Multicollinearity occurs when at least one independent variable is a perfect linear combination of other independent variables (Field, 2013). The variance inflating factor (VIF) can be used to test for multicollinearity among the independent variables. A value of 1 indicates that variables are not correlated, so multicollinearity does not exist. A VIF between 1 and 5 means that low multicollinearity exists and thus the variables are moderately correlated. When the VIF is greater than 5, high multicollinearity exists and this assumption would be violated (GeeksforGeeks, 2021). This assumption was checked before the ordinal logistic regression model was run.
4. The proportionality of odds, means that the effect of independent variables and the odds of being in a higher category of the outcome (e.g. from likely to very likely) is consistent across all levels of the outcome. The test of parallel lines can be used to check this assumption and is done before the ordinal logistic regression model is run. The null hypothesis of this test states that the slope coefficients in the model are the same across the response categories. If the null hypothesis cannot be rejected (p>0.05) the proportional odds assumption holds (UCLA, 2021).

As a strong correlation between independent variables should also be prevented, Kendall's tau test is applied among the ordinal variables in addition to testing the four assumptions. For assessing non-parametric data, Kendall's tau correlation gives the best estimate (Field, 2013).

The results of the ordinal logistic regression analysis indicate if an independent variable can significantly predict the dependent variable. Setting the alpha to 0.05 (95% confidence level), a variable is significant when the p-value is below 0.05. The estimate of the ordinal logistic regression model (b) and the exponential of the estimate, the odds ratio ($exp(B)$), represent the relation between an independent variable and the dependent variable and are crucial for the interpretation of the model. The odds ratio represents the change in odds caused by a unit change in the predictor variable (Field, 2013).

For the independent variables that originally had a category 'Other', some pre-processing was needed to assign a category that most suits according to the filled-in answer by the respondent. Besides, the age is presented in bins for the descriptives but is treated as a continuous variable in the regression analysis.

4.4 Accessibility Analysis

The last part of this methodology discusses the accessibility analysis that is done to compare the accessibility of shared mobility and public transport at the two P+R locations. As defined by Geurs and van Wee (2004), accessibility is the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations using a (combination of) transport mode(s). To compare the accessibility, the cumulative opportunities accessibility measure is applied. This measure counts the number of opportunities which can be reached within a set time or cost threshold (Geurs & van Wee, 2004). Previous research describes that travel time and travel cost are important factors considered by travellers for mode choice (De Witte et al., 2013; KiM, 2021a; Van Veldhoven et al., 2022). Therefore, both factors are considered as thresholds in the accessibility analysis. In addition, the final report of the SmartHubs research project (Geurs et al., 2024) describes that conducting an accessibility analysis is important for the inclusive design of a mobility hub. To express accessibility, the number of destinations indicated by the respondents of the survey and the points of interest (POI) that can be reached within the thresholds are considered as opportunities.

4.4.1 Thresholds

In the accessibility analysis, two types of thresholds are used: a time and cost threshold. Three times are used to draw the service area: 10, 20 and 30 minutes. By analyzing multiple time thresholds, it is possible to see how accessibility changes for the different modes. In addition to the time thresholds, three cost thresholds are set. The accessibility of public transport is chosen as a reference in this analysis, so one could analyse what the accessibility would be for a shared mode given the price for travelling with public transport as the threshold. The set cost thresholds are: €2.50, €5.00 and €7.50. The lower and middle prices correspond with the current prices for the P+R in Maastricht and 's-Hertogenbosch, respectively. It is assumed that the number of opportunities that can be reached by public transport is for each cost threshold equal to the number that can be reached within a time threshold of 30 minutes, as users of the P+R can travel with public transport for a fixed price (the price is not dependent on the time you use the bus).

To determine how many minutes someone can travel with a shared bike, shared e-bike or shared e-moped, a cost scheme for using a shared mode is used. The assumed cost schemes for this analysis are shown in Table 5. As the shared bike is already present at P+R Maastricht Noord and P+R Deutersestraat, the cost scheme of the current system is chosen. Since the shared bikes at P+R Deutersestraat can be used for a fixed price, it is assumed that for each cost threshold, the number of opportunities within 30 minutes of cycling can be reached. GO Sharing and Check are selected as providers because they are present in 's-Hertogenbosch (but not located at the P+R).

Table 5: Cost schemes for shared modes in accessibility analysis

Shared mode	**Provider**	**Cost scheme**
Shared bike: P+R Maastricht Noord	Arriva (2024b)	First 20 minutes: €1.00 After 20 minutes, per minute: €0.05 Daily rate (24h): €9.00
Shared bike: P+R Deutersestraat	Gemeente 's-Hertogenbosch (2024)	Fixed price (P+R-tariff): €5.10
Shared e-bike	GO Sharing (2024)	€0.26 per minute
Shared e-moped	Check (2024)	Starting rate: €1.00 €0.33 per minute

4.4.2 Service area

To apply the cumulative opportunities accessibility measure, a service area is determined that indicates the area that can be reached for a given cost or time threshold. The Network Analysis function in the ArcGIS Pro software is used to draw these service areas. As a service area is associated with a network dataset, this needs to be constructed through the use of multiple data sources. Two network datasets are constructed: one for the shared modes and one for public transport.

The network dataset for shared modes, which is created to determine the bikeability index with data from the Fietsersbond (2022), is used for the accessibility analysis. A few attributes were added to conduct the service area analysis for shared e-bike and shared e-bike, as it only consisted of attributes for the shared bike. The assumed average travel speeds are previously mentioned in section 4.1.1. The same method as explained in Appendix D is applied to determine travel times. Instead of determining routes with the network analyst, the service area option is used. The P+R locations were imported as "Facilities" and the previously mentioned thresholds are filled in as cutoffs for the service area layers that are generated (Esri, 2024d). Using the network dataset for shared modes as active network dataset makes it possible to generate service areas based on the travel times for each shared mode.

To create a network dataset for public transport, General Transit Feed Specification (GTFS) data is used. This data includes the locations of transit lines, their stops as well as the transit schedules (Esri, 2024a). A network of streets also needs to be included in the created network dataset, as users of public transport walk to the transit stops. To create a walking network, OpenStreetMap data is downloaded and filtered on road links where pedestrians are allowed. To calculate the travel time per road link, an average walking speed of 4.25 km/h is assumed (Nichols et al., 2023). After connecting the transit links with the stops on the walking network, the service area option of the network analyst in ArcGIS Pro can be used to generate service areas. The service areas generated show the reachable area from the P+R by public transport and walking within the set threshold at the day and time specified in the network analyst tool. For example, consider a bus trip of 20 minutes with a time threshold that was set at 30 minutes. A service area representing 10 minutes of walking around the bus stop will be drawn.

The configuration of the GTFS-data is an important process, as the data cannot be used when certain information (e.g. about the schedule) is missing (Esri, 2024a). During the development of the network dataset for public transport, missing data resolved in some errors when generating service areas as no suitable output was generated. Therefore, the schedules of the relevant public transit lines were checked on the website of Arriva (2024c) and it service areas were manually drawn per bus stop for each line. For example, considering bus line 60 in 's-Hertogenbosch and a 20-minute threshold. The bus line has four bus stops and travels from the P+R to the first bus stop is a 7-minute travel. So, the remaining walking time around the bus stop is 13 minutes. Travelling to the second bus stop takes an extra minute, so the remaining time for a walking service area is 12 minutes for the 20-minute threshold. As this is the same principle as the service areas are drawn using the GTFS-data, it is expected that the outcomes will not differ in case it would work.

4.4.3 Destinations and POI

In the survey, the respondents were asked to indicate their final destination when travelling from the P+R. As these destinations were already mapped for the analysis of the survey data, the cumulative opportunities measure can be applied to the destinations of the respondents as opportunities. So, for a certain time or cost threshold the accessibility is expressed in the number of destinations that can be reached by public transport, shared bike, shared e-bike or shared e-moped.

Next to the destinations, POI are considered in the accessibility analysis. These could be shops, public buildings or healthcare facilities, and are retrieved from OpenStreetMap (Geofabrik, 2024). Additionally, it is interesting to express the accessibility in the number of POIs that can be reached within a certain cost or time threshold, as these amenities are likely to be visited by the P+R user. The considered POI categories of this research are shown in Appendix E.

5 Results

This chapter discusses the results of this research. The sections in this chapter correspond with the sections in the methodology chapter, and the order of steps in Figure 6. At the end of each section, a summary is provided that answers the related research question(s). Section 5.1 discusses the spatial analysis of peripheral P+R locations in the Netherlands. It highlights characteristics that describe the P+R locations in terms of public transport network, location and shared mobility presence. Based on the analysis, a multi-criteria analysis is conducted to select two study locations. Next, section 5.2 describes the survey response and shows descriptive statistics of the survey results. Section 5.3 starts with presenting the results of the regression analysis after which is reflected on the hypotheses using the outcome of the regression analysis. Lastly, section 5.4 discusses the outcomes of the accessibility analysis for the study locations separately.

5.1 Spatial Analysis P+R locations

The P+R attributes that are analysed will be discussed first, to answer the first research question. Next, the attributes of the P+R locations are evaluated on the MCA criteria and suitable study locations for this research are presented.

5.1.1 P+R Attributes

The P+R locations are categorized into two types, based on their location and role in the mobility network. Using the dataset of SHPV and NDW (2024) and after filtering and checking, this results in 293 remote P+R locations and 62 peripheral P+R locations. According to the data of CROW (2023b), there are 443 P+R locations in the Netherlands. The dataset from SHPV and NDW (2024) is probably not complete as the dataset was created with supplied information from parking operators themselves (both private and public parking operators. For this research, only peripheral P+R are relevant, and their presence in the dataset was checked with information from municipalities. Figure 7 shows the location of the peripheral P+R locations. It is shown that they are mainly located around cities, which corresponds with the goal of intercepting car traffic heading towards the city centre (Zijlstra et al., 2015). The figure shows a P+R in the province of Zeeland that is not close to a city. This location is used for travellers going to the beach.

Figure 7 also shows the public transport types between the P+R and the city centre. It can be seen that in the "Randstad" area almost all P+R have a metro, tram, or multiple public transport types as a connection to the city centre. In contrast, the P+R around the other cities almost all have a bus connection. Figure 8 shows that most peripheral P+R locations have a bus connection, followed by multiple public transport modes to travel the last mile.

Figure 7: Location of peripheral P+R locations and public transport connection

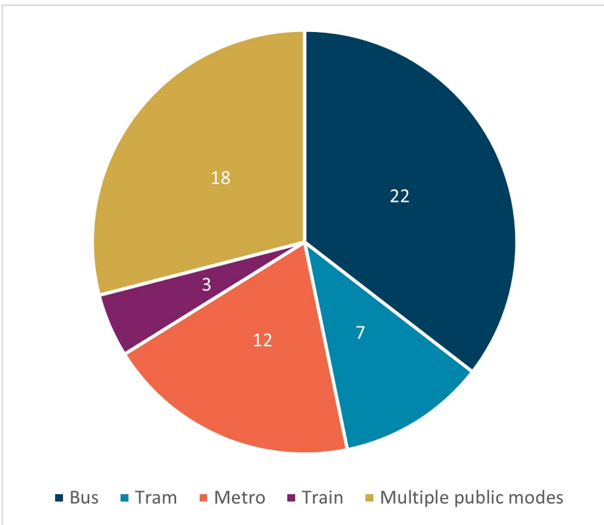


Figure 8: Distribution of P+R locations per public transport type

Previous research into P+R locations advises a public transport connection with a frequency of every 15 minutes or lower to make the P+R attractive and have a high demand (CROW, 2005; Vincent & Hamilton, 2007). Figure 9 shows the public transport frequencies of the peripheral P+R in the Netherlands. 95% of the P+R locations have a frequency equal to or smaller than 15 minutes. Only one location has a frequency larger than 20 minutes, which is the P+R in Ridderkerk, where people can use the ferry every 30 minutes to travel to Rotterdam.

Shared mobility could be an interesting alternative to public transport to cover the last mile to a destination from a P+R location. At 47 of the 62 locations, shared modes are present. Figure 10 shows for each mode the frequency of availability at a P+R. For example, at seven P+R locations, at least one shared bike is available. At the majority of the locations with shared mobility, multiple shared modes are available. For most P+R locations with shared bikes (17 of 20), the OV-fiets is present, which is a station-based roundtrip system (NS, 2024a). In 's-Hertogenbosch, the municipality provides shared bicycles at the three P+R locations which is also a roundtrip system (Visit Den Bosch, 2023). In Maastricht, Arriva (2024a) provides shared bicycles at P+R Noord, which is a station-based one-way system: people can pick up the bicycle at one location and leave it at multiple locations in and around the city centre. The e-bike and e-moped systems are almost all free-floating systems, so the shared modes are not standard available at the P+R locations. At P+R Nijmegen-Noord, the municipality provides e-bikes for the P+R users that can be used for the whole day and must be returned (roundtrip system) (Gemeente Nijmegen, 2023). Lastly, shared cars are present at 18 locations. As people come with their private cars to the P+R, it is unlikely that the P+R users use these cars.

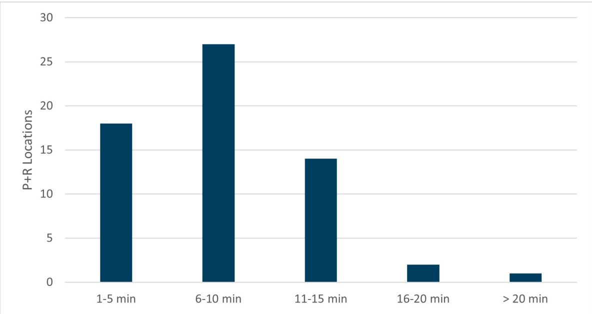


Figure 9: Public transport frequency at peripheral P+R locations

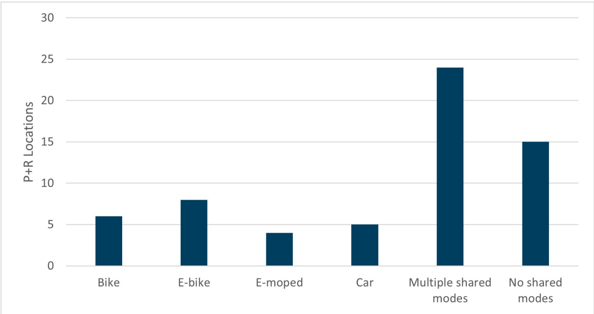


Figure 10: Shared mobility types at peripheral P+R locations

The distance from a national or regional road to a P+R location is for 84% of the cases within 2 kilometres. This is also shown in Figure 11. This corresponds with the recommendations in the literature for a suitable P+R location (CROW, 2005; VenhoevenCS & Rijkswaterstaat, 2020). Figure 12 shows the distribution of distance to the city centre for each P+R location. 65% of the locations lie within 6 kilometres of the city centre. It can also be observed that a relatively large number of P+R locations, namely eight locations, lie further than 10 kilometres from the city centre of the destination. Almost all of these locations are located in the Rotterdam area.

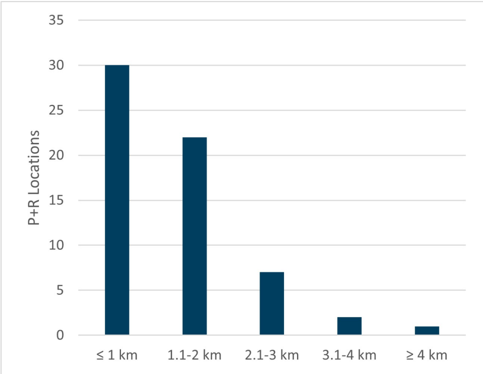


Figure 11: Distance from national/regional road to P+R locations

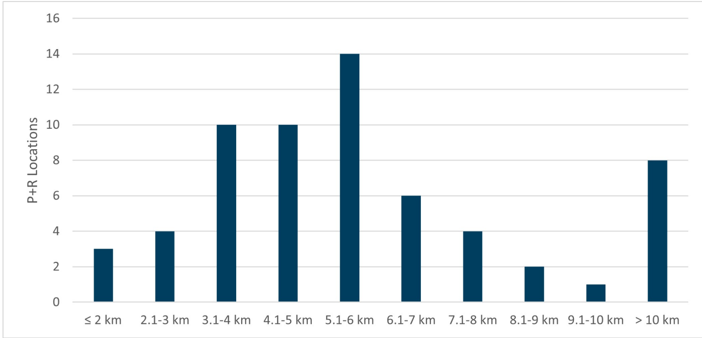


Figure 12: Distance to city centre from P+R locations

The last attribute that is analysed for the peripheral P+R locations is the travel time to the city centre for public transport and shared micromobility. Analysing the travel time makes it possible to compare shared modes with public transport. For 49% P+R locations with at least one shared mode, the public transport connection is faster to reach the city centre. At 21 locations shared bikes are present, and at 5 of the locations the bike is faster than public transport. At 15 of the 23 P+R locations, the e-bike is faster than public transport, whereas the e-moped is at 15 of the 21 cases faster than public transport. For the latter two types of shared modes, it shows that at more than half of the locations where they are available, it is a faster alternative to public transport to reach the city centre. Table 6 shows the overview of the travel time comparison between public transport and shared micromobility.

Table 6: Travel time comparison shared micromobility (SM) and public transport (PT) from P+R to city centre

Shared mode	**Presence of SM at P+R Locations**	**P+R Locations: Travel time SM $\leq$ PT**	**P+R Locations: Travel time SM $>$ PT**
Bike	20	5	15
E-bike	23	15	8
E-moped	21	15	6

5.1.2 Study Area

Section 4.1.2 describes three criteria that are used to select suitable P+R locations for this research. At 42 of the 62 peripheral P+R locations at least one type of shared micromobility is present and are the shared modes and public transport stops located within 200 meters of the parking facilities. Only 17 P+R locations are located within 4 kilometres of the city centre. Eleven P+R locations fulfil all criteria and are listed in Table 7 including their attributes. Some values for the travel time of shared modes have a grey colour since these modes are currently not available at the location.

Table 7: Attributes of potential P+R locations for study area (FF = free-floating system, RT = roundtrip system, OW = one-way system)

P+R Location	Distance [km]		Public transport (PT)		Shared micromobility	Travel time [min]			
	To city centre	From national/ regional roads	Modes	Frequency		PT	Bike	E-bike	E-moped
P+R Weeskinderendijk (Dordrecht)	1.5	1.3	Bus	11-15 min	E-bike [FF]	16	5	4	3
P+R Kalverdijkje (Leeuwarden)	2.8	0.8	Bus	11-15 min	E-moped [FF]	20	11	8	8
P+R De Vliert ('s-Hertogenbosch)	2.8	3	Bus	6-10 min	Bike [RT]	12	10	8	7
P+R Zuiderval (Enschede)	2.9	1.2	Bus	11-15 min	E-bike [FF]	14	9	7	6
P+R Pettelaarpark ('s-Hertogenbosch)	3.2	1.6	Bus	6-10 min	Bike [RT]	10	11	8	8
P+R Laan van NOI (Den Haag)	3.3	2.2	Tram, Metro & Train	1-5 min	All shared modes [Bike = RT, Rest = FF]	3	14	11	10
P+R Deutersestraat ('s-Hertogenbosch)	3.3	2.7	Bus	11-15 min	Bike [RT]	15	12	9	8
P+R Haarlem Spaarnwoude (Haarlem)	3.4	0.5	Bus & Train	11-15 min	Bike [RT] & E-moped [FF]	4	11	8	8
P+R Delft Campus (Delft)	3.5	0.6	Train	11-15 min	Bike [RT] & E-moped [FF]	3	12	9	8
P+R Kardinge (Groningen)	4	0.5	Bus	6-10 min	E-bike & E-moped [FF]	18	15	11	10
P+R Maastricht Noord (Maastricht)	4	1.7	Bus & Train	11-15 min	Bike [OW]	7	14	11	10

Conducting a multi-criteria analysis, the P+R locations are compared and the suitability as the study area is determined using the information of the attributes. The distance to the city centre varies from 1.5 km to 4 km. According to the CROW (2023a) the average distance people walk to facilities and services lies between 0.7 and 1.7 km. The distance to the city centre for P+R Weeskinderendijk in Dordrecht is 1.5 km. This location is not considered in the multi-criteria analysis, as it is likely that a large proportion of the P+R users will walk to their destination, and not consider public transport or shared mobility as a last-mile transportation mode.

Multi-criteria analysis

Table 8 shows the overview of the multi-criteria analysis for the P+R locations, sorted from the most suitable study location to the least suitable study location.

Starting with the **distance from national or regional roads** to the P+R locations as an attribute. Seven locations are located within 2 km of the main road network and have the highest score. The report of VenhoevenCS and Rijkswaterstaat (2020) describes that a P+R is more likely to be used when it is located close to the main road network. The distance from the main road network to the P+R of the three other P+R locations is larger than 2 km. Nevertheless, P+R de Vliert and P+R Deutersestraat score better than P+R Laan van NOI as these are located along the access route to the city centre from the highway (A59/A2). Therefore, these two locations got a middle score and P+R Laan van NOI a low score, as it is located not on the access route to the city centre.

Next, the P+R locations are rated on the **public transport modes and frequency**. Six locations score the best in the MCA on this criterion, as they all have a public transport connection with a frequency between 11 and 20 minutes. P+R Laan van NOI has multiple public transport options and a very frequent connection, so shared micromobility usage is assumed to be limited. Three P+R locations have a frequency of 6 to 10 minutes and are rated with a middle score.

Table 8: Multi-criteria analysis P+R locations

P+R Location	A. Distance from national/regional roads	B. Public transport modes & frequency	C. Shared micromobility	D. Travel time PT vs shared micromobility
P+R Kalverdijkje (Leeuwarden)	+	+	-	+
P+R De Vliert ('s-Hertogenbosch)	o	o	+	+
P+R Zuiderval (Enschede)	+	+	-	+
P+R Pettelaarpark ('s-Hertogenbosch)	+	o	+	o
P+R Laan van NOI (Den Haag)	-	-	+	-
P+R Deutersestraat ('s-Hertogenbosch)	o	+	+	+
P+R Haarlem Spaarnwoude (Haarlem)	+	+	+	-
P+R Delft Campus (Delft)	+	+	+	-
P+R Kardinge (Groningen)	+	o	o	+
P+R Maastricht Noord (Maastricht)	+	+	+	o

A. +: within 2km of national/regional roads; o: > 2 km, but along access route to city centre; -: none of the above
B. +: PT frequency 11-20 min; o: PT frequency 6-11 min; -: PT frequency 1-5 min
C. +: roundtrip or one-way shared micromobility system; o: multiple free-floating shared micromobility systems; -: one free-floating shared micromobility system
D. +: travel time SM < travel time PT; o: travel time SM < total travel time PT (incl. waiting time);
-: travel time SM > travel time PT

The current availability of **shared micromobility** is considered to check at which locations it is the most likely P+R users are already using shared micromobility. The type and number of available shared micromobility services influence the flexibility and reliability, which are two important features for using a shared mode (KiM, 2020a). The locations rated with the highest score all have a shared micromobility service that is a roundtrip or one-way system, which is assumed to be more reliable than a free-floating service. For the P+R locations, except in 's-Hertogenbosch, the OV-fiets is present which is known as the most used shared bicycle service of the Netherlands (KiM, 2021a). P+R Kardinge has multiple free-floating shared modes available. The remaining two P+R locations only have one type of free-floating shared micromobility service and get the lowest score.

The **travel time of public transport and shared micromobility** from the P+R towards the city centre are compared and assessed in the multi-criteria analysis. The locations for which the shared micromobility travel time is lower than the travel time of public transport, all are rated with the highest score. The shared modes at P+R Maastricht Noord all have a longer travel time than public transport. However, considering the public transport frequency, shared micromobility could in total travel time (including waiting time) be faster than using public transport. Therefore, this location is rated with the middle score, together with P+R Pettelaarspark. P+R Haarlem Spaarnwoude, P+R Delft Campus and P+R Laan van NOI all have a fast (train) connection and a good frequency, for which shared micromobility is rarely faster than public transport.

Table 9 shows the ranking of the P+R locations after the multi-criteria analysis. P+R Deutersestraat and P+R Maastricht Noord are the most suitable study locations to run this research. Both locations scored three "+" and one "o" on the attributes. The P+R locations in the second place in the MCA all have two "o" and two "+" scores. The P+R locations ranked third scored an "-" on one of the attributes and finally P+R Laan van NOI in Den Haag is found to be the least suitable location since it scored "-" on multiple attributes.

Looking at the information on occupancy and available parking places of the P+R locations, it can be noticed that the top 5 locations in the multi-criteria analysis, have a good occupancy rate and/or large number of parking places at the P+R. However, some data about occupancy rates might be outdated.

Table 9: Multi-criteria analysis ranking P+R locations including number of parking locations and occupancy rate

Ranking	P+R Location	Parking places	Occupancy rate
1	P+R Deutersestraat ('s-Hertogenbosch)	1100	55%*
	P+R Maastricht Noord (Maastricht)	516	46%*
2	P+R De Vliert ('s-Hertogenbosch)	702	Week: 46% Weekend: 91% (Gemeente 's-Hertogenbosch, 2013)
	P+R Pettelaarpark ('s-Hertogenbosch)	456	Week: 82% Weekend: 68% (Gemeente 's-Hertogenbosch, 2013)
	P+R Kardinge (Groningen)	880	40% (Groningen Bereikbaar, 2021)
3	P+R Kalverdijkje (Leeuwarden)	52	Low (Gemeente Leeuwarden, 2023)
	P+R Zuiderval (Enschede)	75	55% (Galama et al., 2023)
	P+R Haarlem Spaarnwoude (Haarlem)	100	103% (Empaction Mobility B.V., 2019)
	P+R Delft Campus (Delft)	40	*Unknown*
4	P+R Laan van NOI (Den Haag)	155	97% (Metropoolregio Rotterdam Den Haag, 2017)

* *The occupancy rate is calculated by own observation at the P+R locations.*

5.1.3 Summary

The spatial analysis of peripheral P+R locations in the Netherlands aimed to answer the first research question: *What are the characteristics of peripheral P+R locations in terms of location, public transport network and presence of shared mobility?*

The analysis showed there are 62 peripheral P+R locations in the Netherlands, most are located in the Randstad area. In the Randstad area, most P+R locations have a metro, tram or multiple public transport connections. Outside the Randstad area the P+R locations mostly have a bus connection. The public transport frequency has a maximum of every 15 minutes for 95% of the P+R locations. This observation corresponds with the guidelines for developing a P+R location of the CROW (2005), which describes that a public transport connection with a frequency of at least 4 times per hour is desirable. At 47 of the 62 locations shared mobility is present, and at 24 locations more than one shared mode type. Focusing on the location of the peripheral P+R locations, 84% of the locations lie within 2 kilometres of a national or regional road. As a P+R location is ideally located close to the main road network (CROW, 2005; VenhoevenCS & Rijkswaterstaat, 2020), this result shows that the majority of the locations have a desired location. 65% of the locations lie within 6 kilometres of the city centre. Finally, for 49% of the peripheral P+R locations with at least one shared mode, public transport is a faster transportation mode to reach the city centre.

Using the information of the peripheral P+R locations for the MCA, only 11 of the 62 peripheral locations fulfil the criteria described in section 4.1.2 for a suitable study location. This is mainly because the P+R locations are located more than 4 kilometres away from the city centre. This implies that for most P+R locations shared micromobility was originally not considered as a last-mile transportation option in addition to public transport when the P+R locations were realised. This can be explained because most P+R locations were developed before 2010 (Rongen et al., 2022) and shared mobility was rarely used at that time (KiM, 2021a). Based on the travel times for public transport and shared micromobility shown in Table 7, the MCA in Table 8 shows that for seven locations using shared micromobility is faster than public transport (incl. waiting time) when travelling to the city centre. Since travel time is in the literature described as an important factor in mode choice (Huang et al., 2019; Qin et al., 2013; Van Veldhoven et al., 2022), shared micromobility might be more attractive to use at these locations compared to public transport. The accessibility analysis will provide more insight into the accessibility of public transport and shared micromobility for different time and cost isochrones, for the two study locations.

Focusing on the type of shared mobility systems of these eleven locations, the P+R locations in 's-Hertogenbosch are the only locations with a system intended for the P+R users as users do not have to pay additional costs for using a shared bike (Gemeente 's-Hertogenbosch, 2024). External companies exploit the available shared mobility systems at the other P+R locations. Mainly for the P+R locations where a public transport ticket is included in the P+R tariff (P+R Maastricht Noord, P+R Kardinge) or where you get a discount on the parking tariff (P+R Laan van NOI) when using public transport, using shared micromobility is likely to be more expensive which makes using public transport more attractive. The regression analysis could substantiate this assumption when the travel costs are found to be a significant predictor for the intention to use shared mobility, as was the case in previous studies (Christoforou et al., 2021; KiM, 2021a).

5.2 Survey

This section discusses the descriptive statistics of the survey distributed among P+R users of P+R Maastricht Noord and P+R Deutersestraat ('s-Hertogenbosch). First, the survey response is described, before discussing the descriptive statistics. Paragraph 5.2.1 describes the first descriptive statistics related to user characteristics. It presents socio-demographic information of the survey sample and encompasses an assessment of the sample's representativeness. Paragraphs 5.2.2 up to 5.2.5 show descriptive statistics that relate to the travel behaviour characteristics. Next, paragraph 5.2.6 shows the distribution among the digital skills levels. Lastly, paragraph 5.2.7 provides a summary of the descriptive statistics.

The survey resulted in N=750 usable responses for the analysis, considering only completed surveys for consistency purposes. In total, the survey distribution resulted in N=836 responses, so 86 responses are not used for this analysis. For P+R Maastricht Noord, the survey is distributed in various ways. The distribution through flyers on location, the Zuid-Limburg Bereikbaar newsletter and the article on the website of Maastricht Bereikbaar (2024) resulted in N=272 responses. As it is not known how many people accessed the article and read the newsletter, it is not possible to calculate a response rate for this sample. The distribution via the mobility panel of Zuid-Limburg Bereikbaar resulted in N=233 responses, so a response rate of 5.2%. In 's-Hertogenbosch, the survey is only distributed via flyers on the P+R location, resulting in N=331 responses. This results in a response rate of 60.4%.

5.2.1 Socio-demographic characteristics

The socio-demographic characteristics of the respondents are examined and compared with a population sample to assess the representativeness of the collected survey data. Data from the "Onderweg in Nederland (ODiN)" research is used to check the representativeness, which consists of mobility information of the Dutch population. As P+R users often do not live in the municipality where the P+R is located, it is impossible to check the representativeness of the survey sample with the population characteristics of Maastricht and 's-Hertogenbosch. Therefore, ODiN-data from two years (2019 and 2022) is used for a population sample for both locations by selecting multi-modal trips (car + public transport) in the data from people living in municipalities that have the same urbanity class as Maastricht and 's-Hertogenbosch. These two years were chosen to use recent data (within 5 years from now) and exclude the years of the COVID-19 pandemic. The exact selection procedure of the population sample is described in Appendix C.

Table 10 shows the characteristics of the complete survey sample and the survey samples of each P+R location separately, together with the socio-demographic characteristics of the population sample retrieved from ODiN-data (CBS, 2020, 2023b). For P+R Deutersestraat, women are overrepresented, whereas P+R Maastricht shows a more equal distribution of genders. In line with the survey sample, the population sample for 's-Hertogenbosch also shows a larger population of females. The age group 55–64 years has the highest share at both locations, and it can be seen that the youngest age category is the least represented in the survey sample. For both cities, the younger age categories are underrepresented compared to the population sample. Besides, the proportion of respondents in the age groups 45-54 and 55-64 are more represented in the survey sample compared to the population sample of both cities. Almost all people have a Dutch background, whereas, in the population sample, the proportion of people with a Dutch background is a bit lower for both cities.

Looking at the entire survey sample, the majority of the respondents have a high education level, which means that they have completed higher education (HBO) or have a university degree. This is also representative for both cities, looking at the population sample. The occupation status shows that most of the respondents are employed, but the P+R Deutersestraat is used by a larger proportion of self-employed people compared to the P+R Maastricht Noord. Looking at the representativeness, the survey sample consists of more part-time employed respondents compared to the population sample. Besides, there are fewer students in the survey sample compared to the representativeness groups. Lastly, the survey sample of P+R Maastricht Noord has more retired people compared to the population sample. The “other” category of the survey sample consists mainly of people who indicate to have two occupation statuses, for example, both part-time employed and self-employed.

Overall, the sample group has biases towards more female respondents, more older respondents, and more part-time employed respondents compared to the population sample. A study into intermodality (in Dutch: ketenmobiliteit) of KiM (2020b) reports about the characteristics of intermodal trip travellers, which includes P+R users. In comparison to the unimodal traveller, it describes that the general profile of the intermodal trip traveller is more often female, highly educated and young. The survey sample consists of more females than males and the majority of the sample is highly educated, which corresponds with the findings in the study of KiM (2020b). The comparison between the population sample and the survey sample shows that younger people (35-) are underrepresented. One explanation for this could be that, generally, the proportion of young people owning a car is smaller than that of old people (45+) (KiM, 2022). Where young people are more likely to make an intermodal trip by bike and public transport, for example, a smaller proportion of young people that own a car results in fewer young P+R users (KiM, 2020b).

Table 10: Comparison of socio-demographic characteristics of survey respondents, and population sample for Maastricht and ’s-Hertogenbosch (CBS, 2020, 2023b)

Variable	Full sample	P+R Maastricht Noord	P+R Deutersestraat	Population sample Maastricht	Population sample ’s-Hertogenbosch
Gender	*N=746*	*N=435*	*N=311*	*N=126*	*N=156*
Female	63.5%	56.3%	73.6%	48.4%	60.9%
Male	36.5%	43.7%	26.4%	51.6%	39.1%
Age	*N=747*	*N=437*	*N=310*	*N=126*	*N=156*
18 - 24 years	7.0%	5.2%	9.6%	27.0%	26.9%
25 - 34 years	13.3%	11.4%	16.0%	23.0%	17.3%
35 - 44 years	14.8%	15.7%	13.5%	14.3%	6.4%
45 - 54 years	22.2%	24.5%	18.9%	12.7%	17.9%
55 - 64 years	25.5%	25.7%	25.3%	15.9%	16.0%
65 - 74 years	14.8%	14.5%	15.1%	4.8%	9.0%
>75 years	2.4%	3.0%	1.6%	2.4%	6.4%
Migration background*	*N=749*	*N=436*	*N=313*	*N=126*	*N=156*
Dutch background	96.1%	95.0%	97.8%	66.7%	71.2%
European migration background	2.8%	4.1%	1.0%	16.7%	14.1%
Other migration background	1.1%	0.9%	1.3%	16.7%	14.7%
Education level	*N=743*	*N=431*	*N=312*	*N=126*	*N=156*
No education	0.1%	0.2%	0.0%	0.0%	0.0%
Low	9.2%	5.3%	14.4%	9.5%	10.3%
Medium	29.3%	27.6%	31.7%	27.8%	36.5%
High	61.4%	66.8%	53.8%	60.3%	51.9%
Other	0.0%	0.0%	0.0%	2.4%	1.3%
Occupation status	*N=750*	*N=313*	*N=437*	*N=126*	*N=156*
Employed (12 to 30 hours per week)	21.3%	18.2%	25.7%	7.1%	14.1%
Employed (30 hours per week or more)	49.3%	57.3%	38.1%	55.6%	42.9%
Self-employed (full/parttime)	6.9%	4.5%	10.2%	-	-
Working in household or other unpaid activity	2.1%	1.8%	2.5%	0.8%	0.6%
Student	3.0%	2.3%	4.1%	23.8%	21.8%
In retirement	14.8%	13.6%	16.5%	8.7%	14.1%
Unemployed	0.1%	0.2%	0.0%	2.4%	1.9%
Unable to work	0.5%	0.7%	0.3%	0.0%	1.3%
Other	1.9%	1.4%	2.5%	1.6%	3.2%

** Note: the western areas North America, Oceania, Indonesia and Japan are also included in the population sample for European migration background, where these countries belong to the other migration background category in the survey sample.*

5.2.2 P+R usage and travel purpose

The frequency of P+R use is a variable that might influence people's intention to use certain means of last-mile transportation. Figure 13 shows the frequencies of P+R use for the complete survey sample (N=750) and for both study locations separately. The majority of the respondents use the P+R 1 to 5 days per year (39.1%), and only 6.9% use the P+R 4 or more days per week. This distribution corresponds with previous research of Clayton et al. (2014) into the characteristics of P+R users, which shows that the proportion of weekly users is lower than the proportion of monthly users.

The purpose of travel can help to further explain the frequency of P+R usage distribution. The distribution of travel purpose is shown in Figure 14. The figure shows that the largest group of respondents is using the P+R location for shopping purposes, which is 51.9% of the complete survey sample. 29.3% of the respondents use the P+R location to go to their work. This distribution of proportions among travel purposes was also observed in previous research among P+R users (Clayton et al., 2014). It can be seen that there is a difference in the distribution of travel purposes between the two P+R locations studied. A larger share of the respondents of P+R Deutersestraat is using the P+R for shopping purposes compared to the respondents group of P+R Maastricht Noord, respectively 59.1% and 46.7%. In addition, the sample of P+R Maastricht Noord is more used by respondents with a working purpose compared to the respondents in 's-Hertogenbosch. The proportions are, respectively, 32.3% and 25.2%.

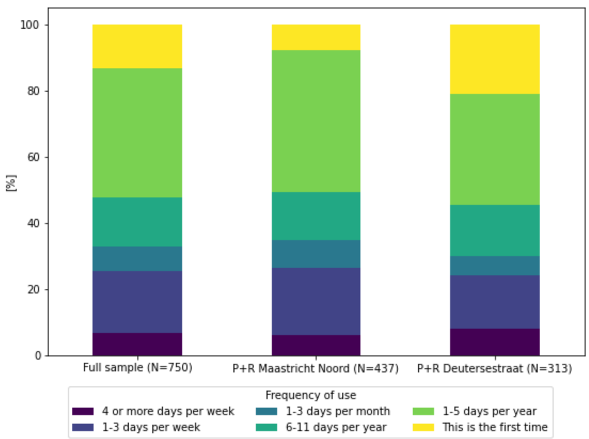


Figure 13: Distribution of P+R frequency of use

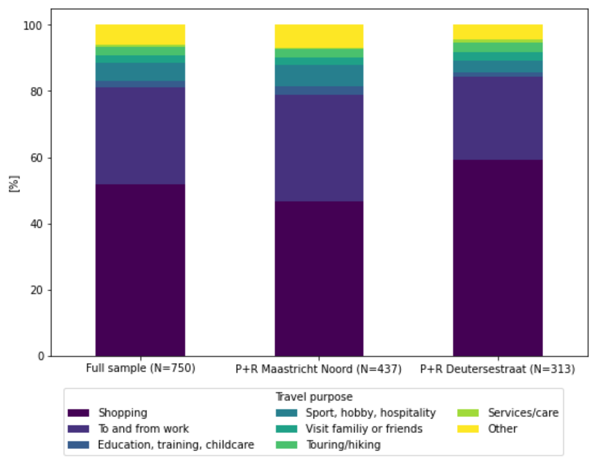


Figure 14: Distribution of travel purpose

Figure 15 combines the frequency of P+R use and the travel purpose for the complete survey sample. It can be noticed that the most frequent P+R users have almost all a working purpose. For the respondent group that uses the P+R locations 4 or more days per week (N=52), 96.2% indicates to use the P+R to go to work. For respondents that indicate to use the P+R 1 to 5 days per year (N=293), the main purpose is shopping. The figure implies a relation between the frequency of P+R use and the main travel purpose.

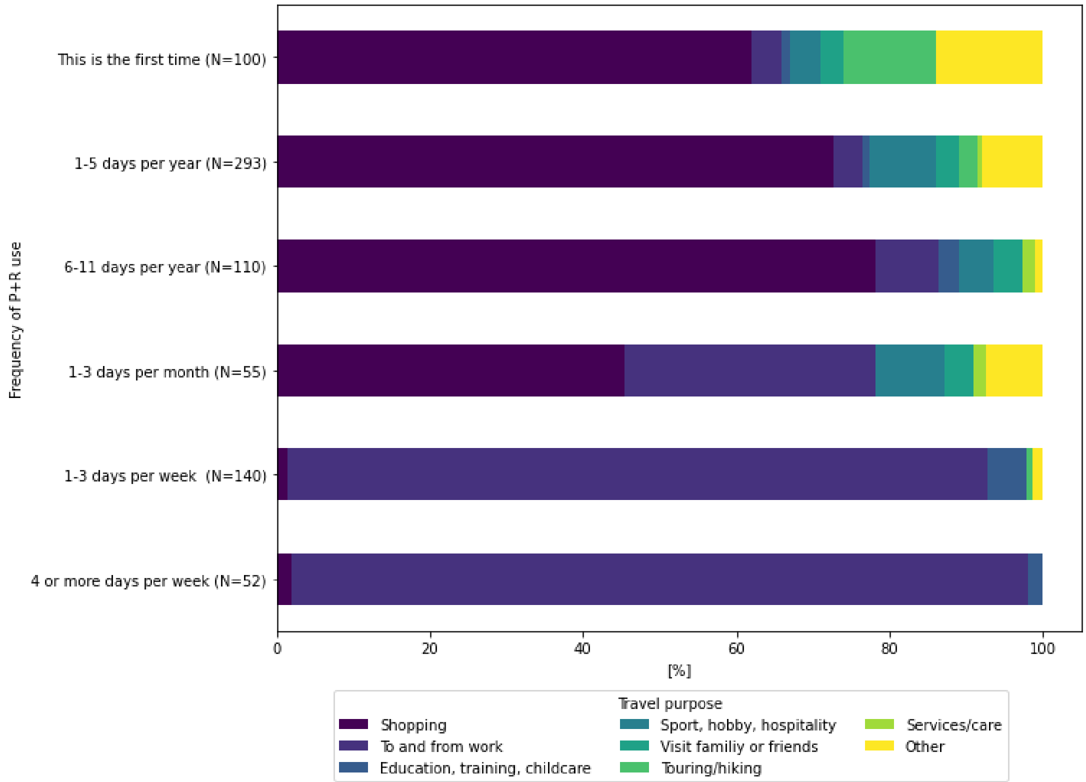


Figure 15: Distribution of P+R frequencies for the complete survey sample and travel purpose distribution within these frequencies

5.2.3 Last-mile transportation mode usage

Multiple last-mile transport modes are available at P+R Maastricht Noord and P+R Deutersestraat to travel to the destination. Before discussing the distribution of the last-mile transportation modes usage, the available transport modes are further introduced.

Public transport
Table 11 shows an overview of public transport options at both P+R locations. P+R Maastricht Noord has multiple public transport connections and users can choose between the bus and train. Travelling towards the city centre takes approximately 12 minutes, or it is a 5-minute journey by train. P+R Deutersestraat has only one public transport connection that takes the P+R user in approximately 10 minutes to the city centre.

Shared micromobility
In Table 12 the details of the available shared micromobility at the P+R locations are presented. Both P+R locations facilitate shared bikes, however, the type of system and number of bikes differ per location. In Maastricht, the shared bikes are provided by Arriva and are a one-way system, which means that the bikes must be picked up and returned at fixed locations in Maastricht. Besides, the bikes can only be used with an app that (un)locks the bike and is used for payment. The system in 's-Hertogenbosch differs from the system in Maastricht. It is a roundtrip system, so the bikes can be picked up at the P+R location and need to be returned to the same location. In addition, no smartphone app is needed, as the P+R user can get a bike key by scanning the parking ticket at a machine. There is no additional fee for using the bike.

Table 11: Overview public transport at P+R locations

	P+R Maastricht Noord	**P+R Deutersestraat**
Bus		
Connections	Line 3, 10 & 30	Line 60
Frequency	Every 15 min*	Every 15 min
Travel time to city centre	12 min*	10 min
Price	€2.40 (P+R ticket - return ticket) €1.88 (PT price - single ticket)	€5.10 (P+R ticket - return ticket) €1.64 (PT price - single ticket)
Train		
Connections	Arriva Stoptrein (Maastricht Randwyck - Kerkrade)	
Frequency	Every 30 min	
Travel time to Maastricht station	5 min	
Price	€1.74 (PT price - single ticket)	

* Line 10 to bus stop Maastricht Mosae Forum/Centrum

Table 12: Overview shared micromobility at P+R locations

	P+R Maastricht Noord	**P+R Deutersestraat**
Shared bike		
Provider/Type	Arriva Deelfiets	Transferium Leenfiets (Municipality 's-Hertogenbosch)
Amount	± 8 bikes	± 55 bikes
Travel time to city centre	14 min (4.1 km)	12 min (3.4 km)
Price	€1.00 (for 20 min) €0.01 per min (after 20 min)	€5.10 (P+R ticket)

Distribution of last-mile transportation modes

Figure 16 shows the distribution of transportation modes that are used at the P+R locations. It shows that there are only small differences between the two samples of the locations studied. 81.9% of the complete survey sample uses the bus to go to their destination. Shared bikes are available at both P+R locations, but it can be noticed from the figure that they are currently not often used by the respondents, as this is only 1.9% of the complete sample. In absolute numbers, only 14 respondents indicated using a shared bike, respectively 10 and 4 respondents for P+R Deutersestraat and P+R Maastricht Noord. Despite this proportion being very low, it is not an odd observation. The user survey on shared mobility in Twente, for example, shows that the proportion of shared mobility users is much lower than public transport users (Rijsman et al., 2023).

In relation to the bus service, the train is used very little at P+R Maastricht Noord (only 3.9% of the survey sample of P+R Maastricht Noord). An explanation for that could be that some P+R users are not in the survey sample, since the parking place close to the station was further away from where the researcher was positioned to distribute flyers. Besides, the train runs to Maastricht station which is located on the other side of the Meuse river than the city centre.

Quite a large proportion of the respondents indicate that they walk to their destination (5.1% of the complete survey sample). As the P+R locations of Maastricht and 's-Hertogenbosch are respectively 4 and 3.3 kilometres located from the city centre, this is not the fastest last-mile mode compared to the available modes. Therefore, this observation was not expected. A small proportion of the walking sample are employees from the Jeroen Bosch Hospital which is located next to the P+R Deutersestraat, and park there since there is too little parking capacity at the hospital parking garages itself. As this is not the target group for this research, the researcher stopped distributing the flyers among this group when it was noticed that these people were employees of the hospital. It might be that a part of the respondents wrongly interpret the question and choose walking, since they walk for example from the bus stop to their destination.

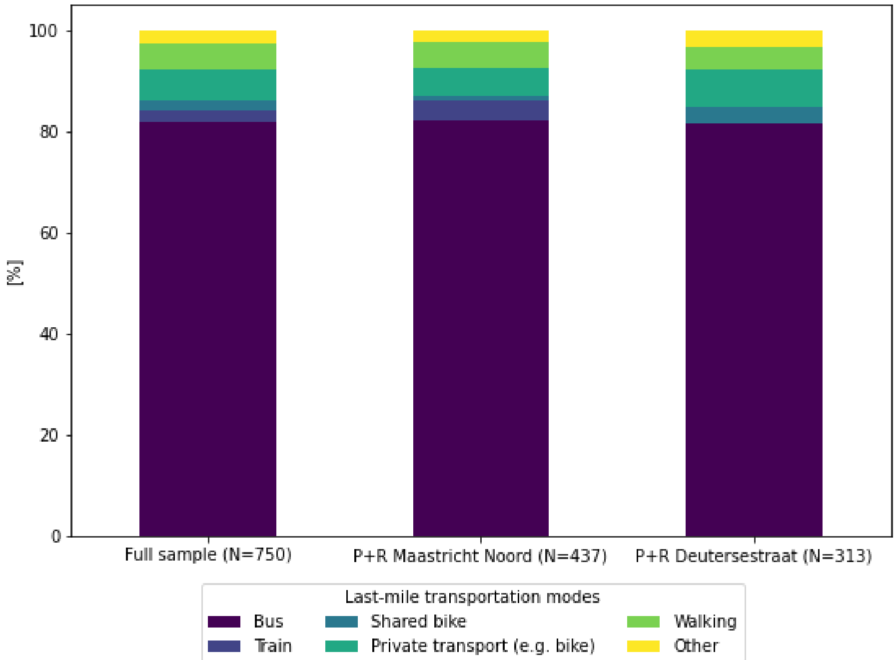


Figure 16: Current distribution of last-mile transportation modes for complete survey sample, and P+R Deutersestraat and P+R Maastricht Noord separately

Just as for the walking mode, it was also not expected to have a percentage of 6.3% that use a private mode to travel the last mile. Again, it is likely that a part of the survey respondents wrongly interpreted this question, as this was also observed by the researcher after the first day of distributing flyers. All respondents that got a flyer were using the bus as was observed, but after checking the results the same day, some respondents answered that they used a private vehicle instead of the bus. In addition, there is no bicycle parking at P+R Maastricht Noord so it is also not facilitated to continue travelling by a private bike for example. At P+R Deutersestraat, some users were approached that used a private bike which was parked in the bicycle parking at the P+R.

Lastly, 2.7% of the respondents indicate to use another mode than the provided answer options. Checking the answers of these respondents, it was found that the majority filled in that they use a car to travel the last mile. Two users of P+R Maastricht Noord indicated that they use the P+R location for carpooling.

Motivation current mode choice

Respondents were asked to indicate their main motivators from a set of eight predefined motivations. Figure 17 shows the distribution for the motivation of using public transport or a shared bike for the complete survey sample. Note that the sample of shared bike users only consists of 14 people. As the majority of the P+R users use public transport as a last-mile transportation mode (Figure 16) and the focus of this study is on shared mobility, only the motivations of these modes are discussed.

For public transport users, the most important motivator is affordability (29.7%). Besides, they value public transport as a quick and comfortable way of travelling to their destination. The most important motivator for shared bike users is that it is a quick way of getting to their destination (22.0%). This finding corresponds with previous research of Garritsen (2022) and Ma et al. (2020) into motivations for using a shared bike. Besides, shared bike users indicate they use a shared bike as it is good for their health and a sustainable way of travelling. Furthermore, the group of respondents that use the last-mile mode because of affordability is larger for public transport compared to shared bikes (29.7% v.s. 16.0%). This might imply that shared bike usage is perceived to be less affordable compared to public transport. Because of the small sample size, it is difficult to conclude from this. Nevertheless, previous research also shows that affordability is less chosen as a motivator for using a shared bike compared to the other motivators (Garritsen, 2022; Knijnenburg, 2023; Rijsman et al., 2023).

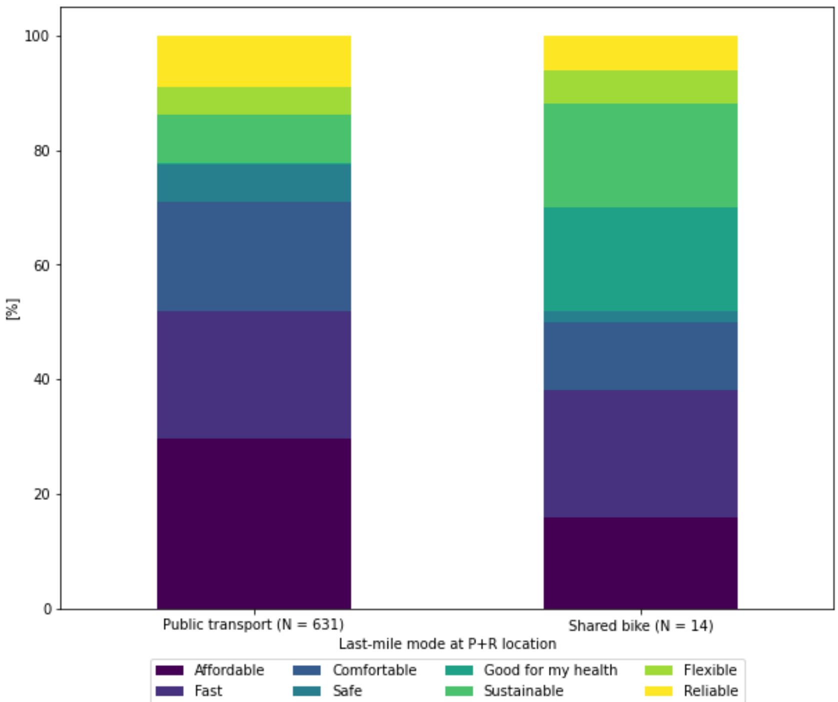


Figure 17: Distribution of motivations to use public transport (sum=1633) or shared bike (sum=50). Respondents could indicate multiple motivations.

5.2.4 Intention to use last-mile transportation modes

Figure 18 shows the distribution of the current use and intention towards last-mile transportation modes at the P+R locations. As only public transport and shared bikes are currently available at the P+R locations, no current use for shared e-bikes and shared e-mopeds is presented in the figure. To know the intention of the respondents towards the four last-mile transportation modes, it was asked how likely people would use another last-mile mode if the current mode that someone is using is not available. For all shared modes, the majority of the respondents are unlikely to use it as a last-mile transportation mode. In contrast, the distribution shows a large proportion of current use of public transport and a relatively larger proportion of P+R users that are likely to use public transport compared to the proportion of respondents that are unlikely to use it as a last-mile transportation mode. This observation is consistent with previous research of Horjus et al. (2022) that studied the intention to use transport modes at a mobility hub, in which respondents were also more likely to use public transport than shared mobility.

Regarding shared micromobility, the figure shows that 24.4% of the respondents indicate that it is likely or very likely that they would use a shared bike when their current mode is not available. For the shared e-bike, this percentage is slightly lower. 19.9% of the respondents indicate that they are (very) likely to use a shared e-bike. Finally, only 6.9% of the respondents indicate that they are likely or very likely to use a shared e-moped when their current last-mile transportation mode is not available at the P+R. A study into the potential of shared mobility usage in the Twente region also found that the proportion of respondents who are likely to use a shared bike is higher than the proportion of respondents who are likely to use a shared e-moped (Rijsman et al., 2023).

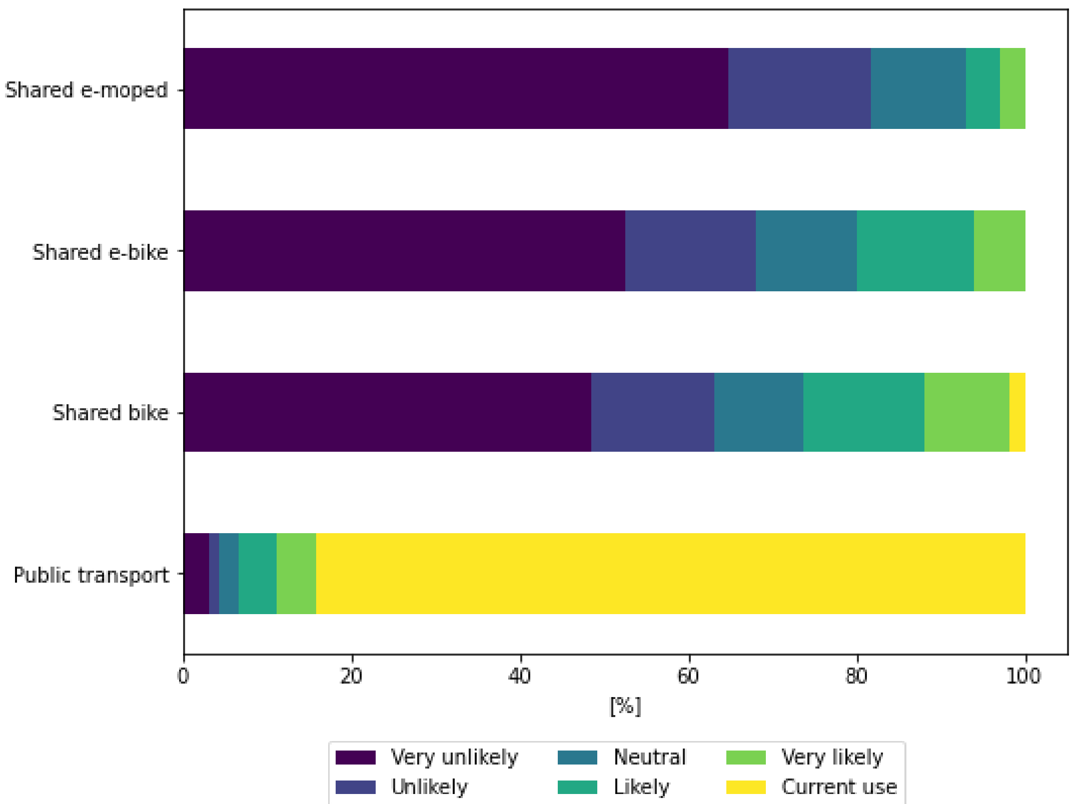


Figure 18: Distribution of current and intended use of last-mile transportation modes at P+R locations (N=750)

Figure 19 shows a Sankey diagram, that visualises the distribution of current usage of last-mile modes at both P+R locations on the left and the intention to use public transport or shared micromobility when the current transportation mode is not available at the P+R. For the current public transport users (N=631), 65.6% indicate that they are not likely to use any type of shared mobility. 34.4% of the public transport users intend to use at least one of the shared modes, of which the largest proportion intends to use a shared bike. Previous research into the impact of shared mobility on modal shift also found a positive intention to use a shared bike among public transport users. The study of van Marsbergen et al. (2022) explored the role of bicycle sharing systems in relation to public transport for Den Haag and describes that 46% of the respondents have used a shared bike as a substitute for bus or tram. For a study in Delft, a substitution of public transport usage between the 33% and 60% for different bike sharing systems was found among the respondents (Ma et al., 2020). For the group that uses a private mode or walks to their destination, the majority indicates that it intends to use public transport, but only a small proportion will use a shared mode as an alternative.

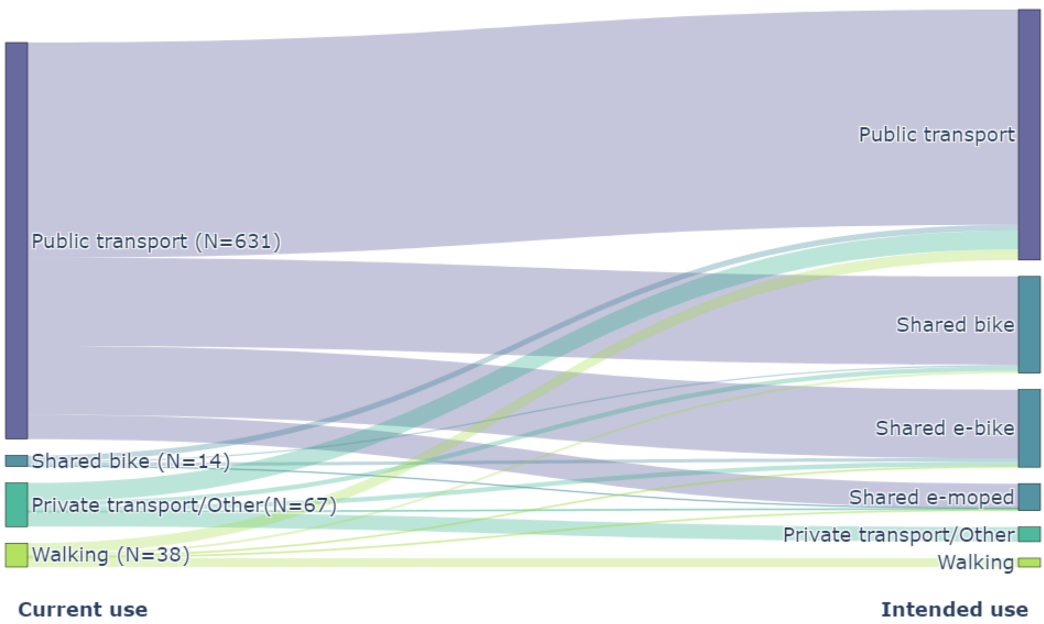


Figure 19: Sankey diagram of the current and intended use of last-mile transportation modes at P+R locations

Table 13 shows the distribution of various user characteristics for the full sample and the users that intend to use shared mobility. The user characteristics in this table all relate to one of the hypotheses, which are described in section 4.3.1. It is visible that the group intending to use shared micromobility has a higher proportion of experienced shared mobility users compared to the full sample. For example, 34.4% of the respondents who intend to use a shared bike have experience with shared mobility. Previous research into the intention to use an e-moped shows similarities, as was found that the proportion of people frequently using shared mobility was larger for the group with a positive intention compared to the full sample (Garritsen, 2022). In addition, the study of Horjus et al. (2022) showed similarities for the intention to use a shared bike with the distribution presented in Table 13 regarding shared mobility experience.

For the socio-demographic characteristics, no big differences are visible between the full sample and the respondents who intend to use shared mobility. This differs from previous research, where the proportion of younger people is larger for the group that intends to use shared mobility compared to the proportion of the same age group of the full sample (Garritsen, 2022; Horjus et al., 2022). A difference is visible when looking at the digital skills levels. The proportion of level 1 skilled respondents is lower for all three intention groups in comparison with the full sample, which implies that the intention to use shared mobility is higher among more digitally skilled people. The same was also observed in the study of Garritsen (2022).

Table 13: Distribution of user characteristics for all respondents and the groups that intend to use shared micromobility

Variable	Full sample	Intention to use:		
		Shared bike	Shared e-bike	Shared e-moped
Gender	*N=746*	*N=183*	*N=149*	*N=52*
Female	63.5%	60.7%	66.4%	63.5%
Male	36.5%	39.3%	33.6%	36.5%
Age	*N=747*	*N=182*	*N=147*	*N=51*
18 - 24 years	7.0%	3.8%	6.1%	17.6%
25 - 34 years	13.3%	13.2%	11.6%	13.7%
35 - 44 years	14.8%	12.1%	12.2%	9.8%
45 - 54 years	22.2%	26.9%	24.5%	25.5%
55 - 64 years	25.5%	32.4%	31.3%	27.5%
65 - 74 years	14.8%	10.4%	12.9%	3.9%
>75 years	2.4%	1.1%	1.4%	2.0%
Education level	*N=743*	*N=181*	*N=147*	*N=52*
No education	0.1%	0.0%	0.0%	0.0%
Low	9.2%	9.4%	8.8%	9.6%
Medium	29.3%	23.2%	27.9%	30.8%
High	61.1%	67.4%	63.3%	59.6%
Other	0.3%	0.0%	0.0%	0.0%
Shared mobility experience	*N=750*	*N=183*	*N=149*	*N=52*
Yes	18.1%	34.4%	24.2%	25.0%
No	81.9%	65.6%	75.8%	75.0%
Frequency of public transport usage	*N=750*	*N=197*	*N=149*	*N=52*
Never	4.8%	4.1%	2.7%	5.8%
1-5 days per year	31.3%	28.4%	32.9%	34.6%
6-11 days per year	19.9%	21.3%	27.5%	13.5%
1-3 days per month	14.1%	13.7%	10.7%	17.3%
1-3 days per week	19.6%	22.3%	18.8%	19.2%
4 or more days per week	10.3%	10.2%	7.4%	9.6%
Frequency of P+R usage	*N=750*	*N=197*	*N=149*	*N=52*
This is the first time	13.3%	13.2%	14.1%	17.3%
1-5 days per year	39.1%	39.6%	40.9%	34.6%
6-11 days per year	14.7%	9.6%	14.8%	15.4%
1-3 days per month	7.3%	6.1%	5.4%	5.8%
1-3 days per week	18.7%	24.4%	20.8%	21.2%
4 or more days per week	6.9%	7.1%	4.0%	5.8%
Trip purpose	*N=750*	*N=197*	*N=149*	*N=52*
To and from work	29.3%	38.6%	28.9%	30.8%
Shopping	52.1%	42.6%	53.0%	55.8%
Services/care	0.7%	1.0%	0.7%	0.0%
Education, training, childcare	2.7%	3.0%	2.7%	0.0%
Visit family or friends	2.7%	3.0%	4.0%	5.8%
Sport, hobby, hospitality	9.5%	8.1%	7.4%	5.8%
Touring/hiking	3.1%	3.6%	3.4%	1.9%
Travel company	*N=750*	*N=197*	*N=149*	*N=52*
I travelled alone	36.5%	43.7%	34.2%	30.8%
I travelled with one other person	48.5%	44.2%	53.7%	51.9%
I travelled with two or more other persons	14.9%	12.2%	12.1%	17.3%
Digital skills	*N=724*	*N=179*	*N=146*	*N=52*
Level 0	0.3%	0.0%	0.0%	0.0%
Level 1	11.0%	7.8%	6.8%	5.8%
Level 2	3.9%	2.8%	0.7%	0.0%
Level 3A	40.9%	40.8%	39.7%	44.2%
Level 3B	43.9%	48.6%	52.7%	50%

Barriers to use last-mile modes
If the respondent answered "unlikely" or "very unlikely" for one or more of the four last-mile transportation modes, the reason for not using that transportation mode was asked. Figure 20 shows the distribution of the barriers for using public transport for the complete survey sample (N=33). The pie chart shows that 42.2% indicates they have no need to use public transport. Besides, 22.2% indicate that they cannot reach their destination easily with public transport and 11.1% think public transport is not flexible. One respondent indicated another barrier and mentioned that his destination is accessible by walking.

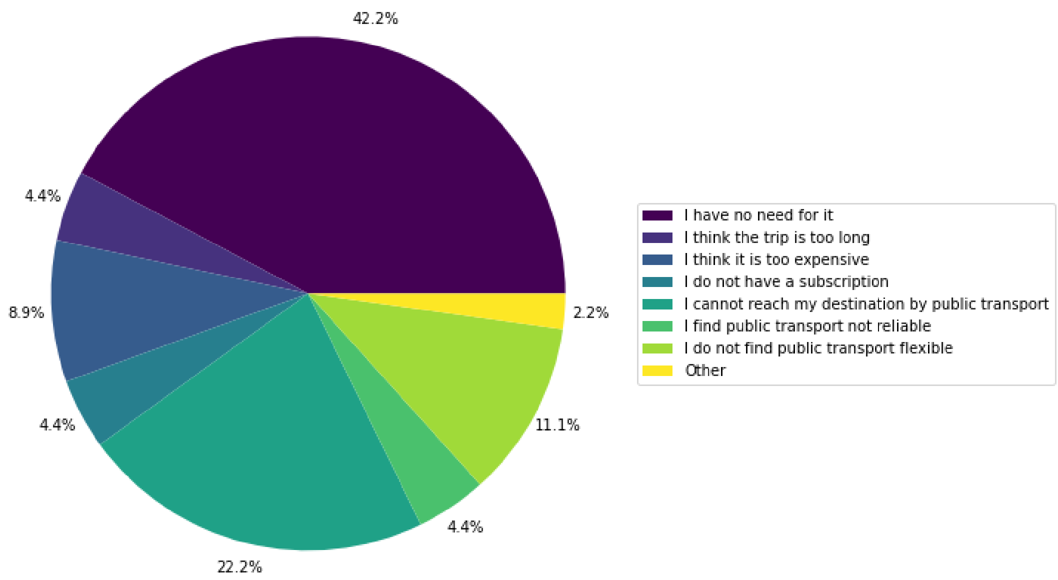


Figure 20: Distribution of the barriers to use public transport (sum=45). Respondents could indicate multiple barriers (N=33)

Figure 21 shows the distribution of the barriers using the shared bike, shared e-bike and shared e-moped. It shows that for all three shared modes, the majority of the sample indicates that they have no need for using shared micromobility, respectively 36.2%, 38.8% and 33.2% for the shared bike, shared e-bike and shared e-moped. This corresponds with a study into shared mobility potential for the region of Twente (Rijsman et al., 2023). Besides, people indicate that they find it a hassle to use or do not know how to use a shared mode.

The figure also shows some differences in indicated barriers between the shared modes. One could see that travelling takes too long is indicated by 8.5% of the sample that does not intend to use a shared bike, while this is only 4.7% and 1.9% for the shared e-bike and shared e-moped respectively. The reason "I do not have a smartphone or other suitable phone" was only added as an option for the shared e-bike and e-moped, as the most used shared bike system works without a smartphone (i.e. OV-fiets). However, one could see that this was for the shared e-bike and shared e-moped also not a major barrier. This corresponds with expectations, as almost all users who filled in the survey had a smartphone. A higher proportion of respondents indicated that using a shared e-moped is dangerous as a barrier, compared to the shared bike and e-bike. Studies of Gkavra et al. (2024) and Knijnenburg (2023) also show a higher proportion for the dangerous barrier for the shared e-moped compared to the shared bike. For the barriers to using a shared e-moped, 8.0% indicated that they do not want to travel with this mode because of the helmet requirement.

For each shared mode also some other barriers were filled in by the respondents. Looking at the other barriers for using the shared bike, multiple respondents indicate that it is not convenient for travelling with children or for shopping. The same reasons are also given for not travelling with a shared e-bike or shared e-moped. For the latter mode, multiple respondents also indicate that they do not want to travel by e-moped because they have no experience with it.

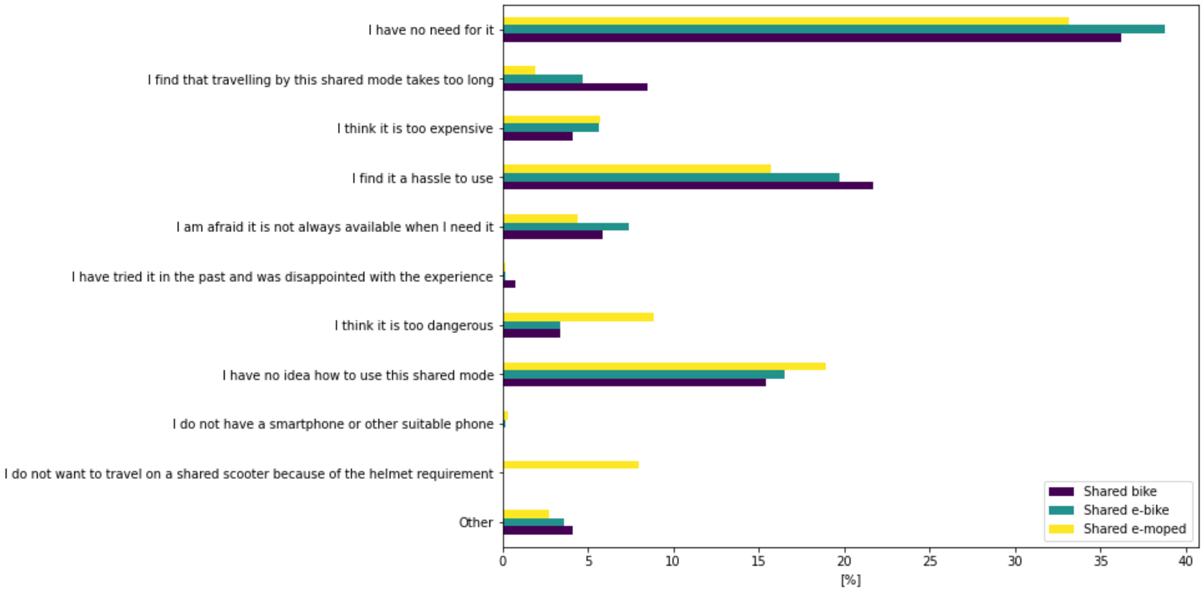


Figure 21: Barriers to use shared bike (sum=682, N=473), shared e-bike (sum=745, N=511) and/or shared e-moped (sum=979, N=613). Respondents could indicate multiple barriers

5.2.5 Destinations of respondents

Survey respondents were asked what their destination was by filling in a 4-digit postcode or the name of the destination location. Mapping this information shows to what extent there is variation among the destinations of the P+R users, and how accessible the destinations are for the different last-mile transportation modes. The destinations of the respondents are shown per P+R location.

P+R Maastricht Noord

Figure 22 shows a map of the Maastricht area with the P+R location, the public transport connections and stops from and to the P+R, and the destinations that the respondents indicated on the PC4 level. As discussed in section 5.2.3, there are three bus lines from P+R Maastricht Noord and a train connection. The map also shows the fastest cycle route to the city centre of Maastricht (i.e. Markt, Maastricht) according to Google Maps (Google, 2024). Looking at the destinations of the respondents, the figure shows that the majority (333 respondents) have a destination in PC4 area 6211, which encompasses the city centre of Maastricht. Most of the respondents indicated as destination “city centre” or something similar. It is assumed that this group of respondents go to a destination in PC4 area 6211. Only 10 respondents indicated that their destination was in the PC4 area around the station (6221) and 7 P+R users went to a location in the same PC4 area as P+R Maastricht Noord (6222).

As the majority of the respondents have a destination within the city centre of Maastricht, Figure 23 shows the destinations on the PC6 level for the respondents that indicated a more detailed location in the survey for the city centre area. Respondents that indicated “city centre” (or something similar) are assumed to have a destination in PC6-area 6221CL (i.e. Markt area). The Markt in Maastricht is the most indicated destination, namely 171 times. 68 respondents indicated that their destination was the Mosae Forum and 11 people said that they were heading to the Vrijthof.

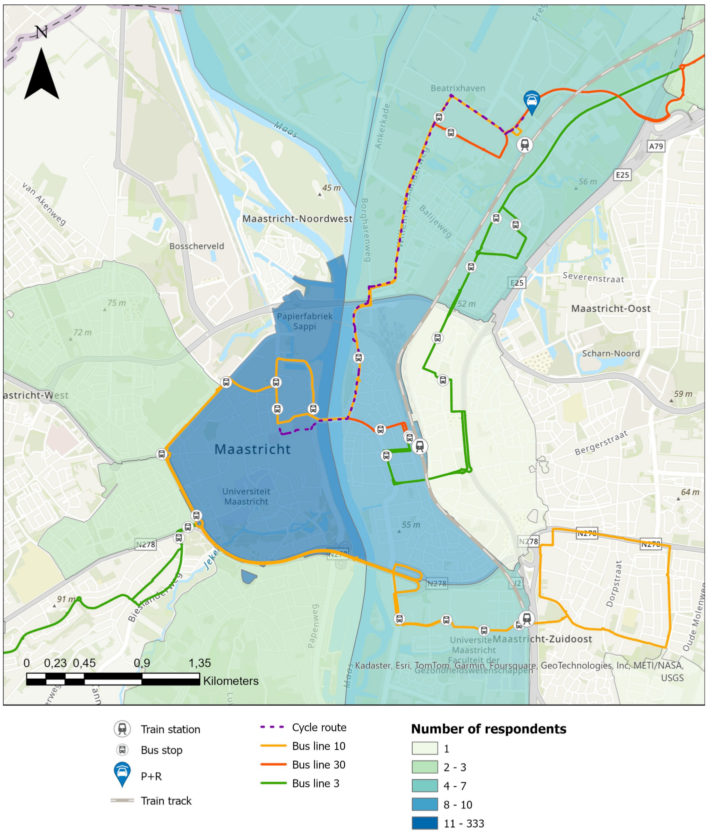


Figure 22: Destinations of respondents on PC4 level for P+R Maastricht Noord (N=436)

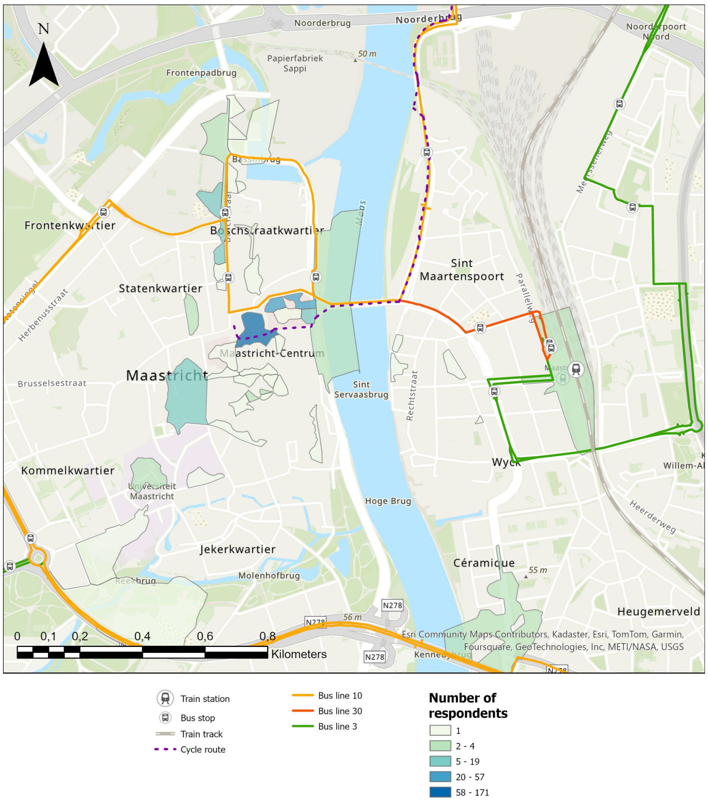


Figure 23: Destinations of respondents on PC6 level for P+R Maastricht Noord (N=334)

P+R Deutersestraat

Just as for P+R Maastricht Noord, also the PC4 level destinations for P+R Deutersestraat are visualised in Figure 24, together with the bus connection from the P+R and the fastest cycling route according to Google Maps (Google, 2024). The figure shows that the majority of the respondents went to a destination in the postal code area that encompasses the city centre of 's-Hertogenbosch (5211), which is a group of 239 respondents. Respondents who answered the destination survey question with "city centre" or something similar were assumed to go to this PC4 area. The difference from the adjacent area (5223) is large, as only six people went to a destination in that area.

Again, the majority of the respondents have a destination within the city centre, so Figure 25 shows for N=255 respondents of the P+R Deutersestraat sample the destination location on PC6 level. 137 respondents indicated to go to the Markt (5211JX), which is in the middle of the city centre of 's-Hertogenbosch. The respondents that indicated "city centre" as a destination in the survey are also part of this group, which is visualised by the dark blue area on the figure. More south of the Markt is PC6-area 5211HH where the municipality is located and is visited by 38 respondents. Next, 19 respondents indicated the Vughterstraat as a destination, which is the green-blue area right of the bus line.

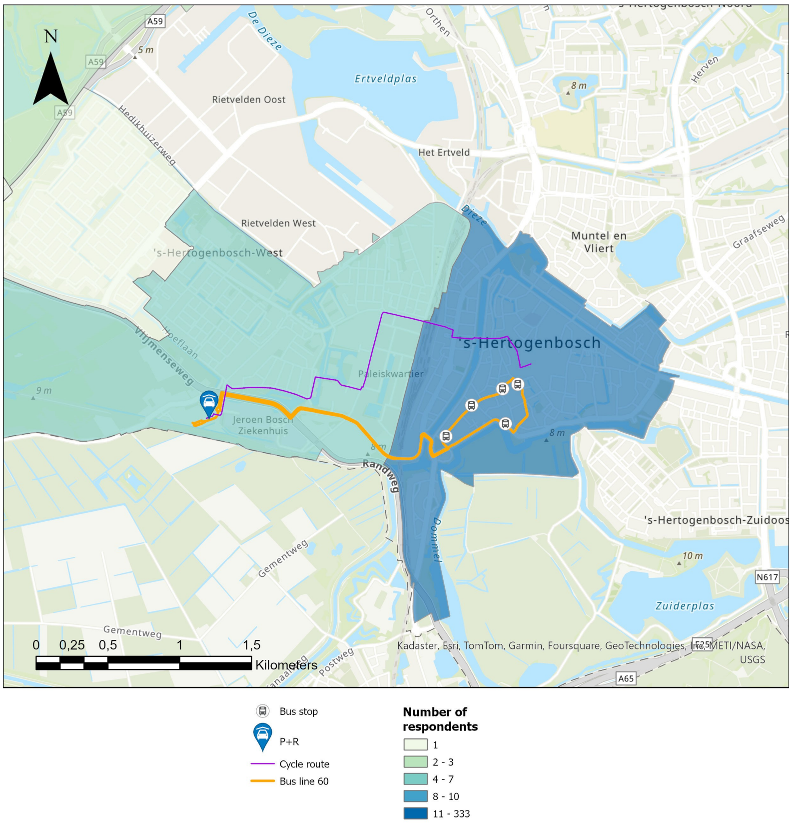


Figure 24: Destinations of respondents on PC4 level for P+R Deutersestraat (N=309)

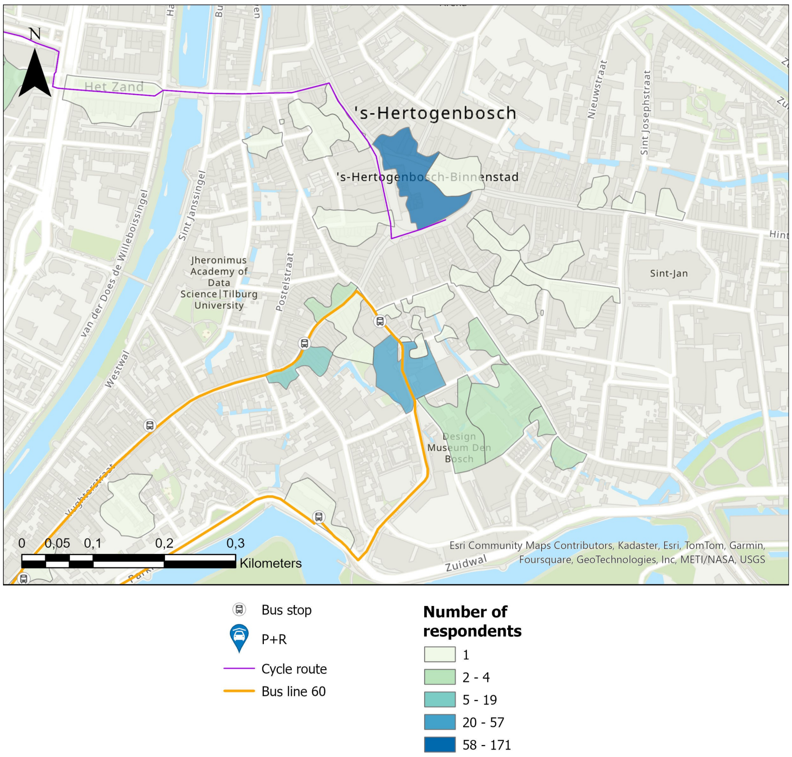


Figure 25: Destinations of respondents on PC6 level for P+R Deutersestraat (N=255)

5.2.6 Digital skills

As described in section 4.2, the digital skills of the respondents were questioned in the survey. To understand the variation of digital skills among the sample, Figure 26 shows the distribution of the respondents (N=721) among the five digital skill levels. The majority of the respondents (43.9%) indicate that they use a mobile phone with internet connection, use trip/planning applications and apps to transfer money, are skilled in online shopping, and are also able to buy public transport tickets and/or use apps for shared mobility (Level 3B). Together with the respondents that have digital skills level 3A, they form the group assumed to be skilled in using shared micromobility. This is the majority of the complete survey sample (84.8%). This result corresponds with the distribution of the digital skills in the study of Horjus et al. (2022), where the majority of the respondents also possess digital skill level 3. The figure shows that only 0.3% of the respondents do not use a mobile phone with an internet connection (Level 0). The proportion of level 0 respondents is low, as the survey was only distributed with flyers in 's-Hertogenbosch which requires a smartphone with internet connection to fill in the survey. Previous research shows that the proportion of older people is larger for the digital skill level 1 sample compared to the digital skill level 3 sample, which implies that older people have less digital skills (Horjus et al., 2022). Looking at the distribution of the age bins per digital skills level for the survey sample of this study, no major difference can be observed between the levels.

Figure 27 shows the distribution for the survey sample of P+R Deutersestraat and P+R Maastricht Noord separately. It can be noticed that the respondents in Maastricht are more digitally skilled compared to the survey sample in 's-Hertogenbosch, as a larger proportion of the respondents are level 3B skilled, respectively 44.9% and 42.7%. Comparing the distribution among the digital skills levels for the two survey samples, it can be seen that the majority of the sample at P+R Deutersestraat is level 3A skilled, whereas in Maastricht the majority is level 3B skilled.

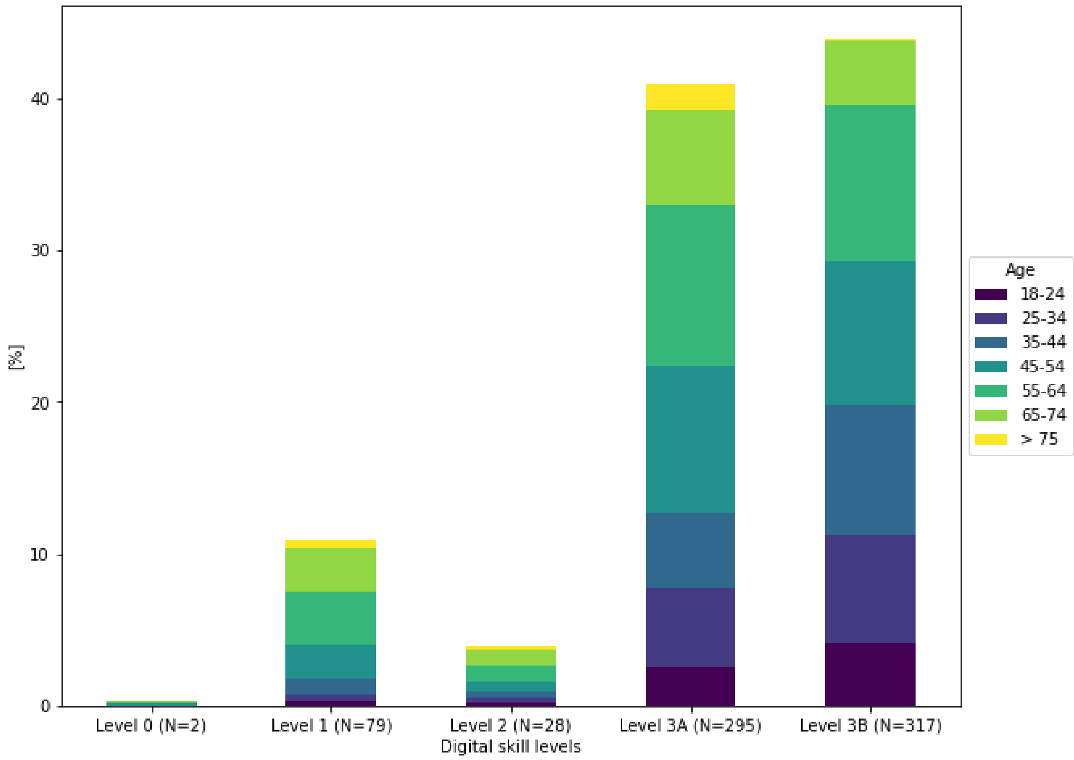


Figure 26: Distribution of digital skills levels among respondents of the survey and age distribution per level (N=721)

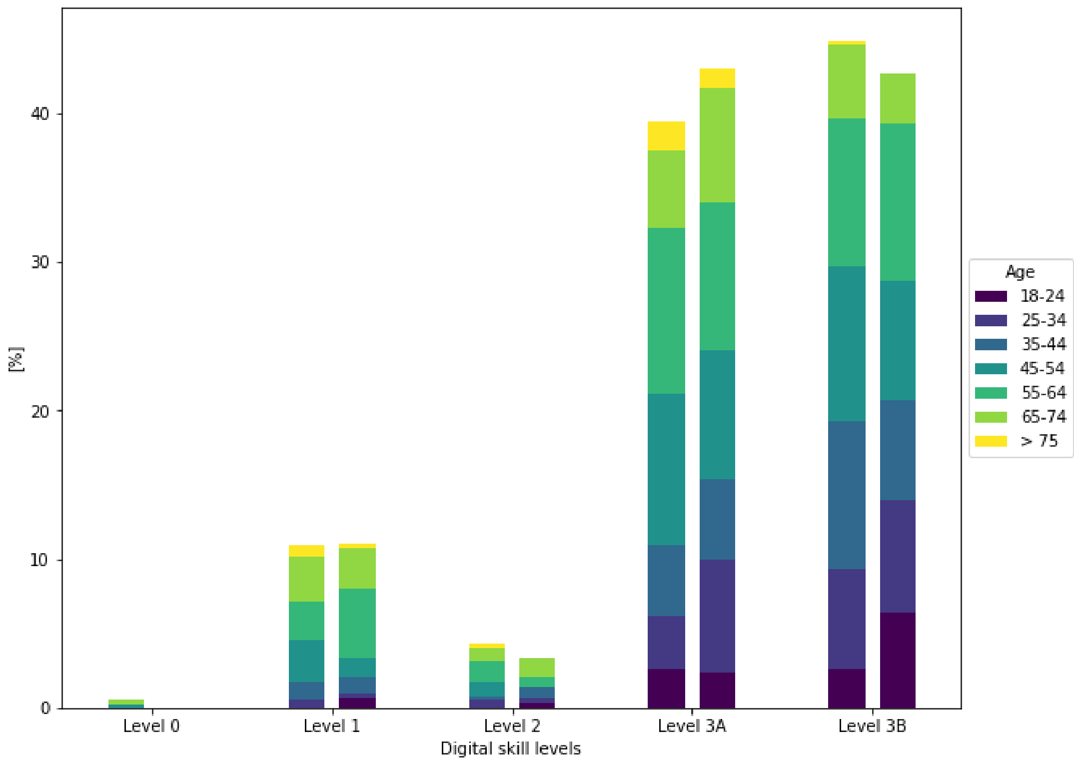


Figure 27: Distribution of digital mobility skills levels for survey respondents of P+R Maastricht Noord (N=421; left bar) and P+R Deutersestraat (N=300; right bar) separately

5.2.7 Summary

The analysis of the descriptive statistics of user characteristics was partly aimed at answering the second research question: *What are the characteristics of P+R users at the studied locations?*

The results of the survey (N=750) showed that users are primarily female, older (45+) and part-time employed. Besides, the majority (96.1%) have a Dutch background and are highly educated (61.4%). Focusing on the frequency of using the P+R locations, 39.1% of the respondents indicated using the P+R 1 to 5 days per year, and only 6.9% use the P+R 4 or more days per week. The majority of the non-frequent users have "shopping" as the purpose, for the frequent users the purpose is "to and from work". Furthermore, the distribution on the current use of last-mile modes shows that 81.9% use the bus to go to their destination, and only 1.9% of the sample uses a shared bike. The intention of P+R users to use shared micromobility is higher compared to the current use. For the current public transport users (N=631), 34.4% intend to use at least one of the shared modes (i.e. shared bike, shared e-bike, shared e-moped) when public transport is not available at the P+R location. Finally, the majority of the respondents of both P+R locations have a destination in the city centre.

Reflecting on the hypotheses, the following can be deduced from the descriptive statistics shown in Table 13. The first hypothesis states that the intention to use shared micromobility is higher among male, younger-aged and highly educated P+R users. No large differences are observed between the proportions of the full sample and the intention to use shared micromobility samples for the gender and education level variables. For the age variable, only an interesting difference is visible for the age category 18-24 years as the proportion of the intention to use a shared e-moped is larger compared to the proportion of the full sample for that same age category. This could indicate a relation between the independent variable age and intention to use a shared scooter, which was found in previous research (Christoforou et al., 2021; Horjus et al., 2022; Sanders et al., 2020). As previously discussed, the descriptives show that the proportion of P+R users with shared mobility experience is higher among P+R users with the intention to use shared mobility compared to the full sample. This corresponds with previous research of Horjus et al. (2022) into the integration of shared mobility at a public transport stop. In this research, the experience with shared mobility was found as a significant predictor of the intention to use shared mobility.

The third, fourth and fifth hypotheses respectively relate to the variables frequency of public transport usage, frequency of P+R usage and trip purpose. Comparing the proportions of the full sample with the proportions for the intention to use shared micromobility presented in Table 13, no interesting differences can be observed. Relating to the third hypothesis, previous research of Horjus et al. (2022) found the frequency of public transport usage as a significant predictor for the intention to use shared micromobility. As for the other hypotheses, the regression analysis should give insight into these hypotheses' relations and significance.

The sixth hypothesis states that P+R users who travel alone have a higher intention to use shared mobility compared to P+R users who travel with other persons. The descriptive statistics only show an interesting difference between the proportion of the intention to use a shared bike and the full sample proportion. This might imply a higher intention towards the use of a shared bike among P+R users who travel alone. The last hypothesis that relates to the descriptive statistics states that P+R users with a higher digital skills level have a higher intention to use shared mobility. Previous research found a significant relation (Garritsen, 2022; Garritsen et al., 2024; Horjus et al., 2022), but the descriptives only show an interesting difference in the proportion of level 1 skilled respondents between the full sample and the intention to use shared micromobility samples.

Based on the descriptive statistics of Table 13, some interesting differences between the samples are noticeable. The regression analysis discussed in the next section will check which relations are significant to accept or reject the hypotheses.

5.3 Data Analysis

This section discusses the results of the regression analysis. Additionally, it assesses the hypotheses presented in section 4.3 of the methodology chapter.

5.3.1 Regression Analysis

An ordinal logistic regression analysis is conducted in SPSS. Four runs with different settings and input are done to see if the model performance improves and to make sure the assumptions are not violated:

- **Run 1:** Model with no changes applied to the data.
- **Run 2:** Model with changes to the following independent variables:
  - Distance: variables changed from metres to kilometres
  - Occupation status: reference category changed to "in retirement"
  - Migration background: European migration background and other migration background merged because of low counts
  - Digital skills level: Level 0 and Level 1 merged because of low counts
- **Run 3:** Model with changes to the following independent variables, in addition to the changes done for run 2:
  - Trip characteristics: changed 5-point Likert scale to 3-point Likert scale (unimportant-neutral-important) because of low counts and violating proportional odds assumption
  - Occupation status: categories unemployed and unable to work are merged, as the unemployed category had only one count
- **Run 4:** Model with changes to the bikeability index, in addition to the changes done for run 3: respondents with a destination further away than 7 kilometres got a "missing value" for the index. Because of the settings in SPSS, these respondents are excluded from the analysis (IBM, 2018).

Each run is done with the original 5-point Likert scale (5L) for the answer categories of the dependent variable and with a 3-point Likert scale (3L), as increasing the number of responses per category can improve the model performance. The categories very unlikely and unlikely are merged into one category, as well as the categories likely and very likely.

Table 14 provides an overview of the model performance for the conducted runs. For each shared mode, it indicates if the assumption of no multicollinearity and proportional odds are met, which are prerequisites for using the model. Besides, three statistical measures are presented that help to evaluate the model performance:

- **Model Fitting Information** can be used to check if the model with the predictor variables (final model) performs better than a model that only fits an intercept to predict the outcome. If the significance level is below 0.05, the null hypothesis that the model without predictors is as good as with predictors can be rejected (Norusis, 2011; UCLA, 2021).
- **Goodness-of-fit tests** are used to determine if the predicted probabilities deviate from the observed probabilities in a way not predicted by the multinomial distribution. If the p-value is lower than the chosen significance level (e.g. $\alpha = 0.05$), the predicted probabilities deviate from the observed probabilities in a way not predicted by the multinomial distribution. So, a p-value higher than the set significance level indicates a better goodness-of-fit for the Pearson and Deviance measures (Minitab, 2024).

- **Pseudo R^2-statistics** are derived from the R^2-statistic used in linear regression, where a higher R^2-value indicates that the model explains more of the variation to a maximum of 1 (IBM, 2023a). However, as these measures do not have the same interpretation as standard R^2 values, they should be interpreted with caution (UCLA, 2021). A larger R^2-statistic indicates a better model, and since the different measures can give contradictory conclusions they are all three included in the table (IBM, 2023a).

Table 14 shows that the multicollinearity assumption is met for all runs and all shared modes. The proportional odds assumption is violated for some of the runs with the intention to use a shared bike as the dependent variable. Using an ordinal logistic regression model with violated assumptions is not possible. Therefore, only run 1 with the 5-point Likert scale (1-5L) and run 3 and 4 with the 3-point Likert scale (3-3L & 4-3L) remain in selecting the best model.

Comparing these three models, little differences between the statistical measures can be observed. Based on the statistical measures, run 3 with the 3-point Likert scale (3-3L) is selected as the ordinal regression model that performs the best. The model fit information shows a significant p-value for all three modes and a high p-value for the Deviance goodness-of-fit measure. Based on the Pseudo R^2 measure, run 1-5L has better values for the Cox & Snell measure and Nagelkerke measure. However, the changes to the model input (e.g. merging categories with low counts) give better estimate values for some categories of independent variables, and the McFadden measure does show higher values than run 1-5L. Therefore, using model run 3-3L is preferred to use as ordinal logistic regression model.

Run 4-3L shows better model performance according to the statistical measures than run 3-3L. However, changing the bikeability index to a missing value for the respondents with a destination above the 7 km travel distance resulted in 116 respondents that are not considered in the logistic regression model. Therefore, using model run 3-3L is not preferred, since for the discussion of the descriptive statistics all respondents are considered.

Table 14: Overview of ordinal logistic regression model results and model performance

Run	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Scale dependent variable	**5L**	**5L**	**5L**	**5L**	**3L**	**3L**	**3L**	**3L**
				Shared bike				
Multicollinearity assumption	✓	✓	✓	✓	✓	✓	✓	✓
Proportional odds assumption	✓	X	X	X	X	X	✓	✓
Model fit information	χ^2=206.85 p <0.001	χ^2=201.08 p <0.001	χ^2=175.33 p <0.001	χ^2=180.12 p <0.001	χ^2=168.87 p <0.001	χ^2=310.63 p <0.001	χ^2=139.11 p <0.001	χ^2=139.38 p <0.001
Goodness-of-fit	Pearson: p=0.051 Deviance: p=1.000	Pearson: p=0.032 Deviance: p=1.000	Pearson: p=0.026 Deviance: p=1.000	Pearson: p=0.006 Deviance: p=1.000	Pearson: p=0.123 Deviance: p=1.000	Pearson: p=0.075 Deviance: p=1.000	Pearson: p=0.037 Deviance: p=1.000	Pearson: p=0.061 Deviance: p=1.000
Pseudo R^2	C&S = 0.255 Nagelk = 0.271 McFad = 0.104	C&S = 0.248 Nagelk = 0.264 McFad = 0.101	C&S = 0.220 Nagelk = 0.235 McFad = 0.088	C&S = 0.264 Nagelk = 0.280 McFad = 0.108	C&S = 0.213 Nagelk = 0.257 McFad = 0.136	C&S = 0.357 Nagelk = 0.430 McFad = 0.250	C&S = 0.179 Nagelk = 0.216 McFad = 0.112	C&S = 0.211 Nagelk = 0.253 McFad = 0.133
				Shared e-bike				
Multicollinearity assumption	✓	✓	✓	✓	✓	✓	✓	✓
Proportional odds assumption	✓	✓	✓	✓	✓	✓	✓	✓
Model fit information	χ^2=103.35 p=0.007	χ^2=97.20 p=0.014	χ^2=76.19 p=0.016	χ^2=83.33 p=0.004	χ^2=93.08 p=0.041	χ^2=88.40 p=0.028	χ^2=76.24 p=0.016	χ^2=78.31 p=0.011
Goodness-of-fit	Pearson: p=0.098 Deviance: p=1.000	Pearson: p=0.097 Deviance: p=1.000	Pearson: p=0.255 Deviance: p=1.000	Pearson: p=0.085 Deviance: p=1.000	Pearson: p=0.116 Deviance: p=1.000	Pearson: p=0.124 Deviance: p=1.000	Pearson: p=0.131 Deviance: p=1.000	Pearson: p=0.203 Deviance: p=1.000
Pseudo R^2	C&S = 0.137 Nagelk = 0.147 McFad = 0.055	C&S = 0.129 Nagelk = 0.139 McFad = 0.052	C&S = 0.103 Nagelk = 0.110 McFad = 0.041	C&S = 0.132 Nagelk = 0.142 McFad = 0.053	C&S = 0.124 Nagelk = 0.152 McFad = 0.079	C&S = 0.118 Nagelk = 0.145 McFad = 0.075	C&S = 0.103 Nagelk = 0.126 McFad = 0.064	C&S = 0.125 Nagelk = 0.153 McFad = 0.079
				Shared e-moped				
Multicollinearity assumption	✓	✓	✓	✓	✓	✓	✓	✓
Proportional odds assumption	✓	✓	✓	✓	✓	✓	✓	✓
Model fit information	χ^2=132.24 p <0.001	χ^2=129.18 p <0.001	χ^2=103.05 p <0.001	χ^2=107.60 p <0.001	χ^2=128.11 p <0.001	χ^2=117.60 p <0.001	χ^2=96.53 p <0.001	χ^2=86.62 p=0.003
Goodness-of-fit	Pearson: p <0.001 Deviance: p=1.000	Pearson: p <0.001 Deviance: p=1.000	Pearson: p <0.001 Deviance: p=1.000	Pearson: p <0.001 Deviance: p=1.000	Pearson: p=0.011 Deviance: p=1.000	Pearson: p <0.001 Deviance: p=1.000	Pearson: p=0.76 Deviance: p=1.000	Pearson: p <0.001 Deviance: p=1.000
Pseudo R^2	C&S = 0.171 Nagelk = 0.194 McFad = 0.088	C&S = 0.168 Nagelk = 0.190 McFad = 0.086	C&S = 0.136 Nagelk = 0.154 McFad = 0.069	C&S = 0.167 Nagelk = 0.189 McFad = 0.085	C&S = 0.166 Nagelk = 0.238 McFad = 0.151	C&S = 0.154 Nagelk = 0.220 McFad = 0.139	C&S = 0.128 Nagelk = 0.183 McFad = 0.114	C&S = 0.137 Nagelk = 0.195 McFad = 0.121

Table 15 shows an extract of the parameter estimates of the ordinal logistic regression models of the intention to use a shared bike, shared e-bike or shared e-moped. It only presents the significant variables (p-value <0.05). As the missing values are excluded listwise in SPSS (IBM, 2018), the regression analysis is conducted with data of N=704 respondents. For the ordinal independent variables in this model, Kendall's tau correlation test was applied but no strong correlation that could be problematic was found. The complete set of parameter estimates including the standard errors of the individual regression coefficients (Std. Err.), Wald statistic, significance level and the 95% confidence interval can be found in Appendix F. The significant independent variables are marked with a * in Table 15.

Table 15: Significant parameter estimates of the ordinal logistic regression model of the intention to use a shared bike, shared e-bike or shared e-moped (N=704)

	Shared bike		Shared e-bike		Shared e-moped	
	b	Exp(B)	b	Exp(B)	b	Exp(B)
Threshold						
Intention to use shared mode = unlikely	1.778	5.917	-0.519	0.595	-2.288	0.101
Intention to use shared mode = neutral	2.376*	10.760	0.179	1.196	-1.077	0.341
Locations						
Age	0.009	1.009	-0.004	0.996	-0.035*	0.965
Shared mobility experience = No	-1.942*	0.143	-0.763*	0.466	-0.625*	0.535
Shared mobility experience = Yes	0[a]	1	0[a]	1	0[a]	1
Walking difficulty = No	0.898*	2.456	0.502	1.652	-0.524	0.592
Walking difficulty = Yes	0[a]	1	0[a]	1	0[a]	1
Ability to use e-moped = No	-	-	-	-	-19.392	0.000
Ability to use e-moped = I do not know/Never tried	-	-	-	-	-1.155*	0.315
Ability to use e-moped = Yes	-	-	-	-	0[a]	1
Migration background = Dutch background	0.416	1.516	-1.034*	0.356	-0.582	0.559
Migration background = Non-Dutch background	0[a]	1	0[a]	1	0[a]	1
Payment methods at P+R = unimportant	-0.245	0.783	-0.875*	0.417	-0.283	0.754
Payment methods at P+R = neutral	-0.281	0.755	-0.429*	0.651	-0.167	0.846
Payment methods at P+R = important	0[a]	1	0[a]	1	0[a]	1
Availability of transport mode = unimportant	-0.350	0.704	0.520	1.683	1.804	6.072
Availability of transport mode = neutral	-0.899*	0.407	-0.049	0.953	-0.392	0.676
Availability of transport mode = important	0[a]	1	0[a]	1	0[a]	1
Facilities at P+R location = unimportant	0.062	1.064	0.439	1.551	-0.075	0.928
Facilities at P+R location = neutral	-0.198	0.820	-0.340	0.712	-0.504*	0.604
Facilities at P+R location = important	0[a]	1	0[a]	1	0[a]	1
Pseudo R^2 (McFadden)	0.112		0.064		0.114	

Link function: Logit
[a] This parameter is set to zero because it is redundant.
* Significant at the 0.05 statistical level (95% confidence level)

The age is a significant independent variable for the intention to use a shared e-moped. The estimate indicates that younger people have a higher intention to use a shared e-moped compared to older people. This finding corresponds with previous research of Garritsen et al. (2024) and Horjus et al. (2022) that also found a higher intention to use shared micromobility for younger age groups. Besides, shared micromobility is currently more used by younger age groups than older age groups (KiM, 2021a), and young people have a more positive attitude towards shared micromobility compared to old people (Rijsman et al., 2023). The same relation is also visible for the intention to use a shared e-bike, but it is not significant and weak. For the intention to use a shared bike, the estimate shows the opposite (i.e. higher intention for older people). As the estimate is not significant and weak, it is difficult to conclude from this.

The shared mobility experience is the only variable that significantly influences the intention of using a shared bike, shared e-bike or shared e-moped. The model shows that someone with prior experience of using shared mobility has a higher intention to use a shared mode at the P+R. For the shared bike even 6.993 (1/0.143) times larger than someone without any prior experience in using shared mobility.

The study of Horjus et al. (2022) also found the shared mobility experience as a significant predictor for the intention to use shared micromobility. Studying the barriers to using shared mobility in Figure 21 of section 5.2.4, it was found that not knowing how to use a shared mode and that it is a hassle to use, have a relatively high proportion. This implies indirectly that an important barrier is limited if people know how a shared mobility system works.

The walking difficulty is a significant predictor for the intention to use a shared bike. The model shows that someone who has no walking difficulties has a higher intention to use a shared bike. The same relation between the predictor and dependent variable is also found for the intention to use a shared e-bike. This corresponds with previous research that found a declined intention to use a shared bike for persons with walking difficulty (Garritsen et al., 2024). For the intention to use a shared e-moped, an opposite relation is found: someone with walking difficulties has a higher intention to use a shared e-moped. If people intend to use a shared e-moped as an alternative for walking from the P+R to their destination, this relation is understandable. The same relation was found in the research of Garritsen et al. (2024) that describes that respondents with a walking difficulty are relatively more positive about sitting, motorized vehicles.

The independent variable ability to use an e-moped was only included in the regression model with the intention to use a shared e-moped as the dependent variable. The odds of people who are unsure if they can use a shared e-moped or people who never tried an e-moped intending to use a shared e-moped are 3.175 (1/0.315) times smaller than those of someone who indicates they can use a shared e-moped. This relation corresponds with the findings on the barriers to use shared mobility in Figure 21 of section 5.2.4. It was found that not knowing how to use a shared e-moped, is an important barrier for people. This is also described in previous studies into shared e-moped usage (Garritsen, 2022; Knijnenburg, 2023; Rijsman et al., 2023).

The migration background is a significant predictor for the intention to use a shared e-bike. Someone with a migration background has a higher intention to use a shared e-bike compared to someone with a Dutch background. The same relation was also found for the intention to use a shared e-bike, although this relation is not significant. These findings correspond with the relation found for the intention to use a shared bike in previous research of Garritsen et al. (2024). For the intention to use a shared bike, someone with a Dutch background has a higher intention, although this relation is also not significant. The relation is explainable, as the OV-fiets is a shared bike system that is currently more used in the Netherlands than free-floating shared e-bike and e-moped systems. Therefore, more people with a Dutch background might be familiar with a shared bike system (CROW, 2024b). However, it should be noted that the group of respondents with a non-Dutch background is fairly small (N=24) making these parameter estimates less reliable.

A trip characteristic that is found to be significant for the intention to use a shared e-bike, is the payment methods at the P+R location. The regression model shows that someone who values payment methods as important for mode choice has a higher intention to use a shared e-bike. This corresponds with previous research of Horjus et al. (2022) that also found payment methods as a significant predictor for the intention to use shared mobility. Previous research into the impact of different bike-sharing systems on modal shift describes motivations to become a bike-sharing user (Ma et al., 2020). It shows that the type of payment method is an important motivator for using bike-sharing. Users of a free-floating bike-sharing system value the convenience of an app to pay, whereas users of the OV-fiets value paying with the OV-chipkaart as important (Ma et al., 2020). Since the regression analysis shows that intended users of a shared e-bike indicate payment options at the P+R as an important characteristic, providing multiple payment options might be positive for shared e-bike usage. For the intention to use a shared bike or shared e-bike, the same relation is observed but not significant.

The availability of a transportation mode at the P+R is a significant independent variable for the intention to use a shared bike. Someone who values this characteristic as important has a higher intention to use a shared bike. Previous research into the barriers to using shared micromobility found that being afraid that a mode is not present is a barrier to using it (Rijsman et al., 2023). This is also indicated as a barrier by the respondents of this study, as shown in Figure 21. Mainly with free-floating shared mobility systems availability of the mode at each moment of the day is sometimes a problem and might be the reason that people are not using it. A study into shared mobility in the Netherlands also describes that unavailability is an important barrier that could limit the adoption of bike sharing (KiM, 2021a). Since a potential user values the availability of a transportation mode according to the regression analysis, it is important to make sure that shared modes are mostly available and that people are informed well about the availability. For example, the NS app provides real-time information on the availability of OV-fietsen at stations. For the shared e-bike and e-moped, no significant relation is found in the regression analysis.

Lastly, the facilities at the P+R location are a significant predictor for the intention to use a shared e-moped. Someone who values this factor as important in the mode choice has a higher intention to use a shared e-moped. This is an interesting observation, as one could argue that people intending to use a shared e-moped start directly with travelling their last mile and make no use of the facilities, such as a bus shelter. Nevertheless, it could be that this factor is important for all P+R users in general independent of the last-mile mode they choose. For example, the study of Horjus et al. (2022) showed that this characteristic is significantly important for the use of public transport. For the other two shared modes, no clear and significant relation between this independent variable and the dependent variable is observed.

5.3.2 Hypotheses

Section 4.3.1 presented a set of hypotheses for this study based on findings in the literature. This section will assess the hypotheses using the outcomes of the regression analysis. An overview of the hypotheses and whether they are accepted or rejected based on the results is shown in Table 16.

Table 16: Overview of the hypotheses and the assessment based on the regression analysis

Hypotheses	Shared bike	Shared e-bike	Shared e-moped
H1: The intention to use shared micromobility for last-mile trips from a P+R is higher among male, younger-aged and highly educated P+R users. - Male P+R users - Younger-aged P+R users - Highly educated P+R users	 X X X	 X X X	 X ✓ X
H2: The intention to use shared micromobility for last-mile trips from a P+R is higher among P+R users with shared mobility experience.	✓	✓	✓
H3: Frequent public transport users have a higher intention of using shared micromobility for last-mile trips from a P+R compared to non-frequent public transport users.	X	X	X
H4: Frequent P+R users have a higher intention to use shared micromobility for last-mile trips from a P+R compared to less frequent P+R users.	X	X	X
H5: P+R users with a working purpose have a lower intention of using shared micromobility for last-mile trips from a P+R compared to people with a leisure purpose	X	X	X
H6: P+R users travelling alone have a higher intention of using shared micromobility for last-mile trips from a P+R compared to P+R users that travel with others.	X	X	X
H7: P+R users with a higher digital skills level have a higher intention of using shared micromobility for last-mile trips from a P+R.	X	X	X
H8: The significantly important trip characteristics for the intended use of shared micromobility differ per shared mode.	✓	✓	✓
H9: The quality of the bike infrastructure affects the intention of using shared micromobility for last-mile trips from a P+R.	X	X	X

The first hypothesis cannot be accepted as a whole, but as it consists of multiple independent variables relating to the intention of using shared micromobility these are split. The descriptive statistics of the variables in Table 13 show no large differences between the proportions of the full sample and the intention to use shared micromobility samples, except for the lowest age category for the intention to use a shared e-moped. For this dependent variable, the regression analysis showed that age is a significant predictor describing that younger-aged people have a higher intention to use a shared e-moped. This also corresponds with previous research findings (Garritsen et al., 2024; Horjus et al., 2022). For the other independent variables, no significant positive relation was found for the intention of using shared micromobility. An explanation for this could be that our sample consists of more female and older-aged people, in contrast to previous studies (Garritsen et al., 2024; Horjus et al., 2022) that found these predictors as significant.

The second hypothesis relates to the shared mobility experience for which interesting differences between the proportions of the full sample and intention to use shared micromobility samples were found in the descriptive statistics of Table 13. The regression analysis showed that this is the only independent variable that was found to be significant for all three dependent variables in Table 15. Therefore, the hypothesis is accepted. As discussed earlier, this corresponds with previous research of Horjus et al. (2022).

Hypothesis 3 can not be accepted as the frequency of public transport use is not a significant predictor for the intention of using shared micromobility. As discussed in section 5.2.7, no interesting differences were observed between the proportions of the full sample and the proportions for the intention to use shared micromobility. Therefore, this outcome of the regression analysis corresponds with expectations. The estimates that are presented in Appendix F show that P+R users with a public transport frequency of 4 or more days per week have a higher intention to use shared micromobility than P+R users with a lower public transport usage frequency. However, the estimates are insignificant for all three shared modes. Previous research of Horjus et al. (2022) also included this predictor in the regression model, but no significant relation was found for the intention of using shared mobility.

The fourth hypothesis is also not accepted based on the outcome of the regression analysis. This corresponds with the expectations, as the descriptive statistics shown in Table 13 also do not show interesting differences between the proportion of the full sample and the proportions of the intention to use shared micromobility. Looking at the parameter estimates for the intention to use a shared bike and shared e-bike (Appendix F), an opposite relation is found although not significant. It implies that frequent P+R users have a lower intention to use shared micromobility compared to less frequent P+R users. An explanation could be that frequent P+R users are in the habit of travelling by public transport and see no reason to deviate from it, whereas non-frequent P+R users are more willing to explore the use of shared micromobility. A similar variable included in previous research is the trip frequency, which describes the number of trips made by a respondent using a specific public transport stop. (Horjus et al., 2022). This predictor was found to be significant in this study, describing that frequent users have a higher intention to use shared mobility. As the studied location is within the city centre, the trips made using this stop are not comparable with the trips from the P+R location which therefore might be a reason that the frequency of P+R usage is not significant.

The fifth hypothesis focuses on the travel purpose of people using the P+R. As previously discussed in section 5.2.7, no interesting differences between the proportions were observed in the descriptive statistics. The regression analysis corresponds with this observation as it shows that the travel purpose was not found to be a significant predictor for the intention to use shared micromobility. Therefore, this hypothesis is rejected. Looking at the parameter estimates, no clear relation between the different purposes can be observed. The variable consists of seven categories, of which one relates to a working purpose and the other six to a leisure purpose. It might be that due to the number of categories, no clear relation could be found. The travel purpose was found to be a significant predictor in previous research into the factors influencing shared e-scooter usage (Guo & Zhang, 2021). This predictor was included as a binary variable (i.e. leisure purpose or no leisure purpose), which differs from the inclusion of the travel purpose in this study.

Hypothesis 6 relates to the travel company of the P+R users. The descriptive statistics of Table 13 show an interesting difference between the proportion of the intention to use a shared bike and the full sample proportion. Previous research also described that single-person households or households without children have a higher intention to use shared mobility (KiM, 2021a). However, the hypothesis is not accepted as the travel company variable is not a significant predictor in the regression analysis. The parameter estimates in Appendix F show the expected relation that P+R users who travel alone have a higher intention to use shared micromobility compared to P+R users who travel with others, but this is not a significant relation.

For hypothesis 7, it was assumed that the digital skills level would be a significant predictor of the intention to use shared mobility based on previous research from Garritsen (2022), Garritsen et al. (2024), and Horjus et al. (2022). The descriptive statistics only show a difference in the proportion of level 1 skilled respondents between the full sample and the intention to use shared micromobility sample.

Therefore, the hypothesis is rejected as no significant relation was found in the regression analysis. For the shared e-bike and shared e-moped, the parameter estimates of the regression analysis show that someone with a higher digital skills level is more likely to use a shared mode. In the survey sample of this study, more than 85% have digital skills level 3, which is a larger proportion compared to the previous studies. This could be an explanation for why no significant relation was found in the regression analysis.

The regression analysis showed that there are three trip characteristics significant and thus important to consider in mode choice at the P+R for the intention to use a shared bike, shared e-bike or shared e-moped. For each shared mode, a different trip characteristic is significant. Therefore, the eighth hypothesis is accepted. This corresponds with previous studies, that also showed that the trip characteristics that are found to be significant differ per shared mode (Garritsen, 2022; Horjus et al., 2022).

The last hypothesis is rejected as the bikeability index was not found to be a significant independent variable in the regression analysis for the three dependent variables. Previous research of Knijnenburg (2023) into the effect of built environment factors and demographics on shared mobility usage shows that built environment factors can be a significant predictor for the number of trips made with shared micromobility. However, the regression model is based on neighbourhood characteristics and predicts the number of trips made, so differs from the approach of this study.

5.3.3 Summary

The regression analysis of this study was aimed at answering the third research question: *What factors influence people's intention to use shared micromobility as a last-mile transportation mode at a P+R location?*

The regression analysis showed that for each type of shared micromobility (bike, e-bike and e-moped) different predictors significantly influence the intention to use it. Only the prior experience of shared mobility usage was found to be significant for all three shared modes and describes that someone with experience has a higher intention of using a shared mode. This finding corresponds with a study of Horjus et al. (2022) that also found the shared mobility experience as a significant predictor for the intention to use shared mobility. In addition, the walking difficulty and availability of transport modes were found to be significant for the intention to use a shared bike. The significance of the latter trip characteristic illustrates that the type of shared micromobility system applied at a P+R location is an important aspect concerning the potential of shared micromobility at a P+R location. Besides, a study of Rijsman et al. (2023) also describes that being afraid that a mode is not present is found to be a barrier to using it.

The migration background and the type of payment methods at the P+R location are significant predictors of the intention to use a shared e-bike. Payment for using a shared mode works currently often with an app. The significance of this variable implies that providing multiple payment options for using shared modes can positively influence shared micromobility usage. The payment options was previously found as a significant predictor in the study of Horjus et al. (2022) into the intention of shared mobility usage.

It was found that younger people significantly have a higher intention to use a shared e-moped than older people. Previous research of Garritsen et al. (2024) and Horjus et al. (2022) also found a higher intention to use shared micromobility for younger age groups. Besides, someone who thinks to have the ability to use an e-moped has a higher intention to use a shared e-moped. Furthermore, someone who values the facilities at a P+R location as important has a higher intention to use a shared e-moped. This trip characteristic was found to be a significant predictor for the intention to use public transport in a study of Horjus et al. (2022).

5.4 Accessibility Analysis

The last part of the results chapter presents the outcomes of the accessibility analysis. This analyses the differences in accessibility between public transport and shared micromobility at P+R Maastricht Noord and P+R Deutersestraat. The accessibility analyses are discussed separately for each location. Per location, first, the accessibility for destinations is examined and then for POI.

5.4.1 P+R Maastricht Noord

P+R Maastricht Noord has in total three bus connections and one train connection, as can be found in Table 11. Having multiple public transport connections means that the actual accessibility differs at every moment of the day depending on which bus or train runs at that specific time. To make a suitable comparison with the accessibility of the shared modes, only bus line 10 is considered as a public transport connection for this analysis. This is the most frequent public transport connection (4x per hour) and runs directly to the city centre which is the destination of most respondents. Besides, it was observed by the researcher during the distribution of the survey that almost all P+R users travel their last mile with this bus line. In addition, waiting time and possible disruptions of the bus service are excluded in the analysis.

Destinations
For P+R Maastricht Noord, 434 destinations were reached in total by the respondents. Figure 28 and Figure 29 show the accessibility expressed in the number of destinations that can be reached for the four transport modes, given a set time or cost threshold. Figure 28 clearly shows that most destinations can only be reached with a time threshold of 20 or 30 minutes for all transport modes. The accessibility of shared micromobility is higher compared to public transport, with the highest accessibility for the shared e-moped. This is also visualised in Figure 32. This observation corresponds with the accessibility analyses conducted for six European cities in the study of Nichols et al. (2023), comparing the walking, cycling, e-scooter and public transport modes. It shows that the number of amenities that can be reached within a 15-minute threshold is larger for a shared bike and shared e-scooter compared to public transport. When considering cost thresholds, a different pattern can be observed. Figure 29 shows that the shared bike has the best accessibility for all three cost thresholds, and the shared e-moped only reaches a comparable amount of destinations for a cost threshold of €7.50. Besides, for the cost threshold of €2.50 public transport shows better accessibility than the shared e-bike and shared e-moped. In line with this finding, a previous study comparing the accessibility of different shared modes considering a cost threshold of €4.45 found better accessibility for a shared e-bike, compared to the accessibility of a shared e-moped (UUM, 2023).

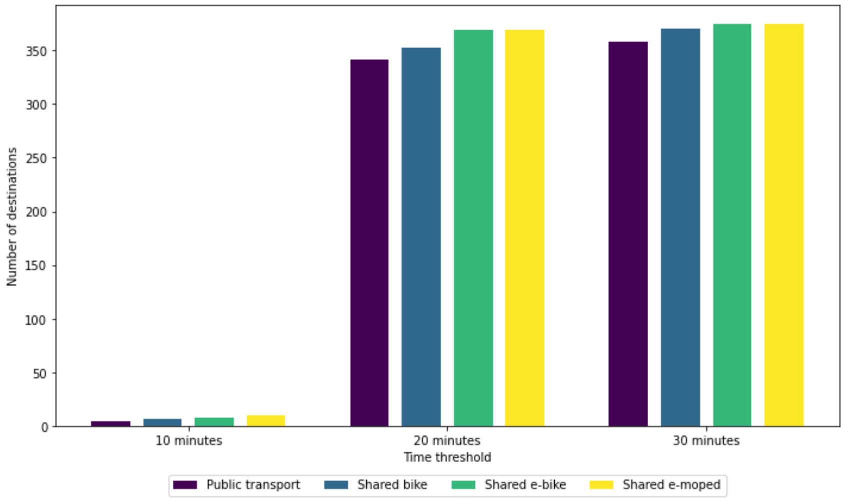


Figure 28: Accessible destinations from P+R Maastricht Noord for time thresholds

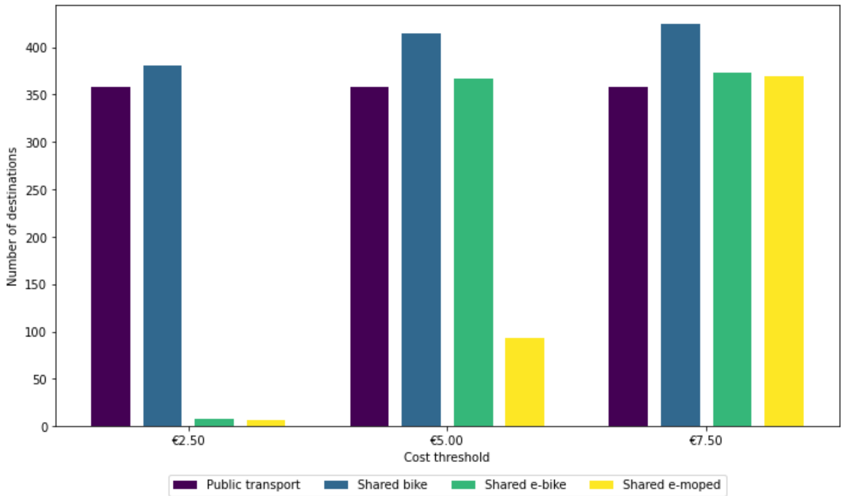


Figure 29: Accessible destinations from P+R Maastricht Noord for cost thresholds

POI

Figure 30 and Figure 31 show the accessibility expressed in POI for the time and cost thresholds respectively. Figure 30 shows the same pattern as for the time thresholds, namely that the shared e-moped has the best accessibility and public transport the worst. As expressed in POI, shared micromobility has better accessibility than public transport for the time thresholds. This corresponds with the findings in the study of Nichols et al. (2023). For the cost thresholds, Figure 31 show the best accessibility for the shared bike for each cost threshold. However, in practise the number of POI will be lower as it is highly unlikely that someone will cycle 100 or 150 minutes for the €5.00 and €7.50 threshold respectively. Besides, the shared bikes can only be used in a predefined service area which is likely to be exceeded with these travel times. The large service area for the shared bike is also visualised in Figure 32. Nevertheless, it shows that the shared bike system of Arriva is a price-friendly alternative to public transport. For the cost threshold of €2.50, the bar for shared e-moped is barely visible as only 11 POI locations can be reached for this threshold. This corresponds with a previous study of UUM (2023) that other shared modes have better accessibility compared to a shared e-moped when a cost threshold is considered.

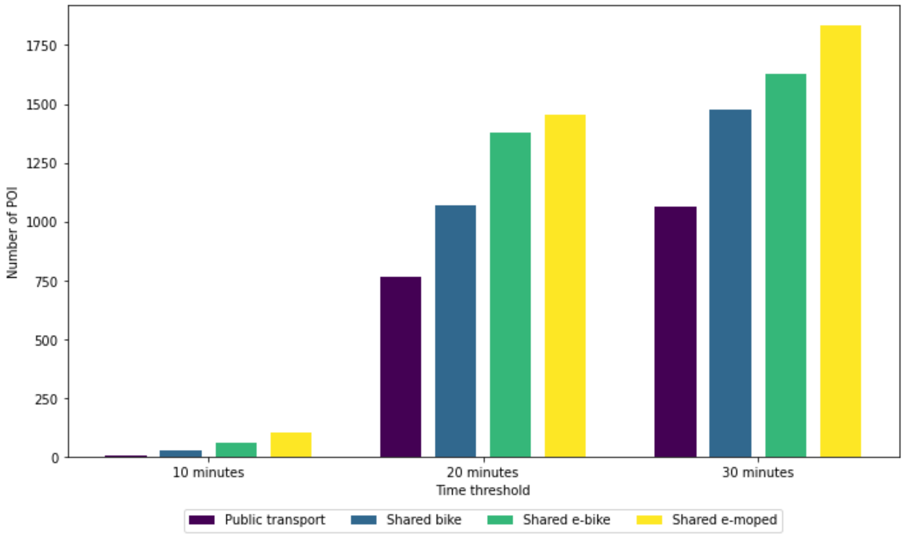


Figure 30: Accessible POI from P+R Maastricht Noord for time thresholds

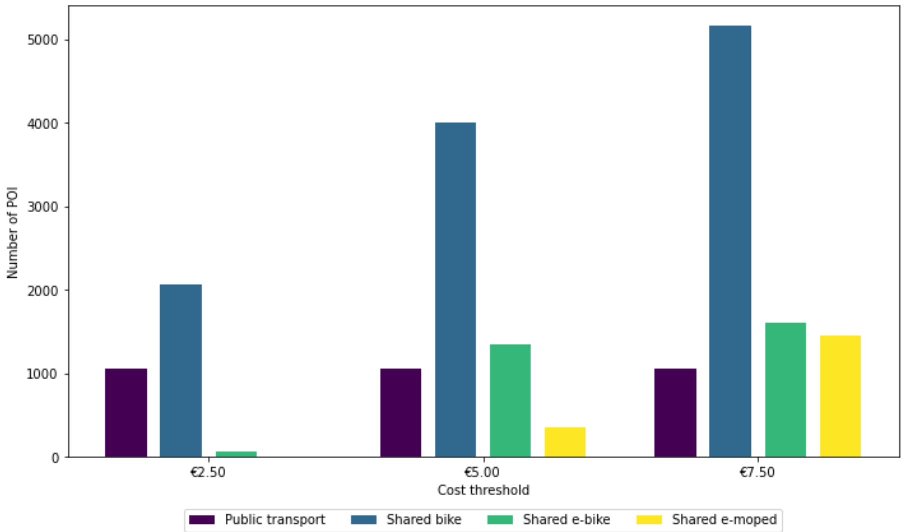
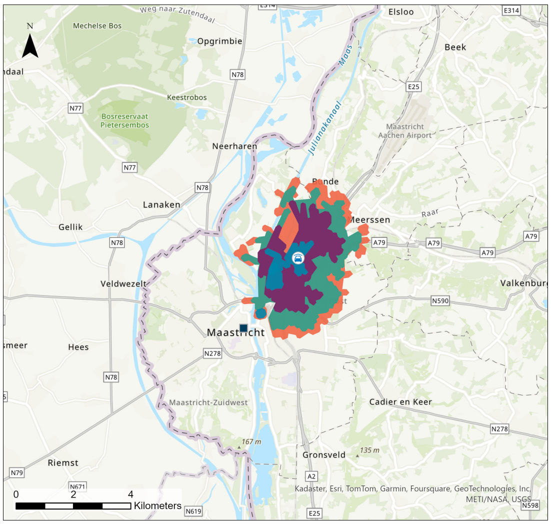
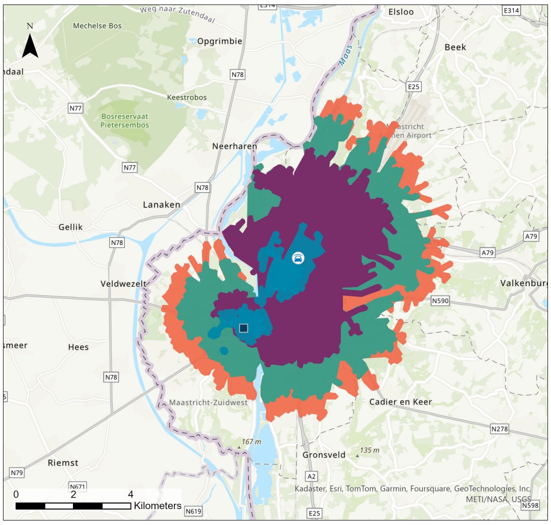


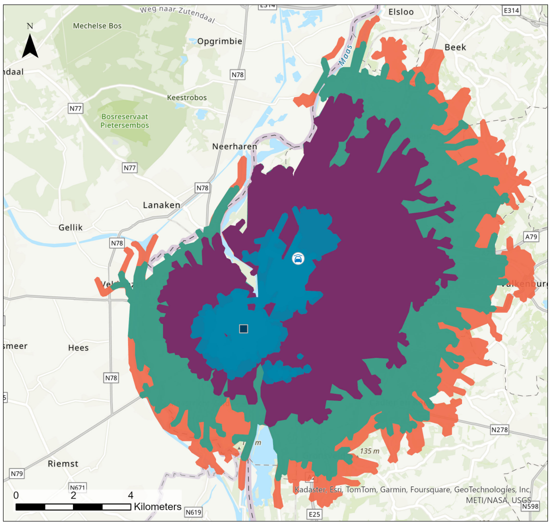
Figure 31: Accessible POI from P+R Maastricht Noord for cost thresholds



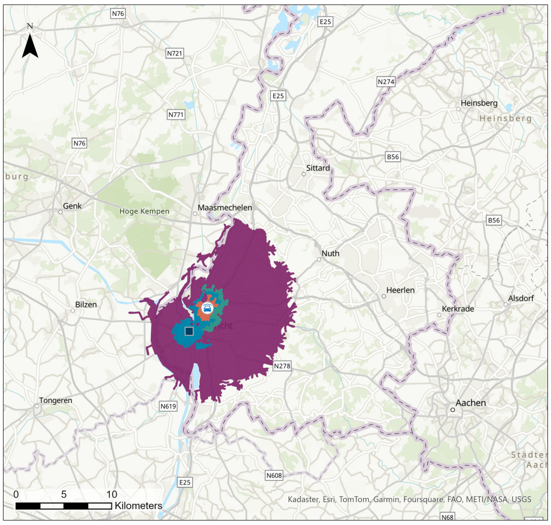
(a) Time threshold: 10 minutes



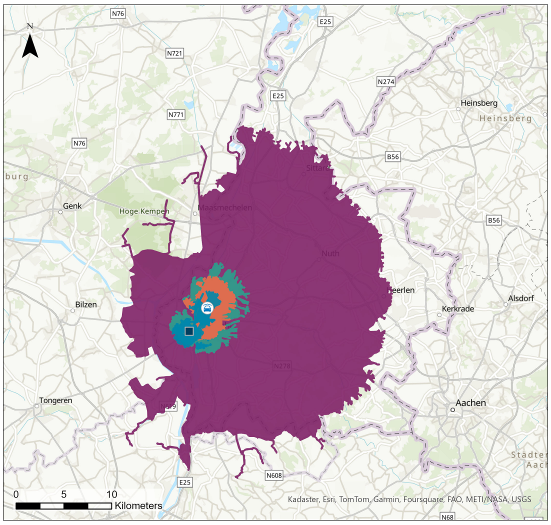
(b) Time threshold: 20 minutes



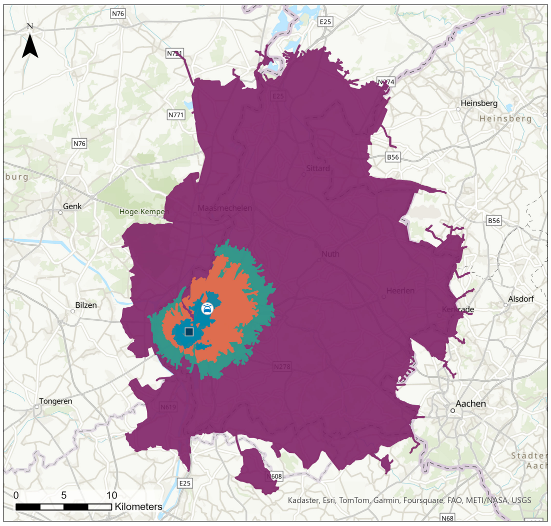
(c) Time threshold: 30 minutes



(d) Cost threshold: €2.50



(e) Cost threshold: €5.00



(f) Cost threshold: €7.50

Legend	Public transport		Shared bike		Shared e-bike		Shared e-moped	
	P+R		City centre					

Figure 32: Service areas for P+R Maastricht Noord

5.4.2 P+R Deutersestraat

P+R Deutersestraat has only one public transport connection departing from the P+R which is bus line 60. This bus line is considered to generate the service areas representing the accessibility of public transport. Again, waiting time and possible disruptions of the bus service are excluded in the analysis.

Destinations

The survey among P+R users of P+R Deutersestraat in 's-Hertogenbosch resulted in 309 destinations that are indicated. The accessibility of destinations for the time and cost thresholds for this P+R location are presented in Figure 33 and Figure 34. Figure 33 shows major differences between the transport modes for the 10-minute threshold. The shared e-bike and shared e-moped have both a much higher accessibility compared to public transport and a shared bike. This corresponds with the findings for P+R Maastricht Noord, and previous research of Nichols et al. (2023) comparing the accessibility of public transport and shared mobility using a time threshold. For the other two time thresholds, the differences are small (max. 8 destinations difference) so they show an almost equal accessibility. The difference is also illustrated in Figure 37. Figure 34 shows the largest difference for the cost threshold of €2.50. Since the shared bike system in 's-Hertogenbosch is a roundtrip system with a fixed price, the accessibility is equal for all three cost thresholds. It can be seen that most destinations for a price of €2.50 can be reached with either public transport or a shared bike. For the other two cost thresholds, the differences are small as can also be seen in Figure 37. Figure 33 and 34 both show that almost all destinations can be reached for a 20-minute or €5.00 threshold, as there is only a small difference in accessibility with the upper thresholds (i.e. 30 minutes and €7.50).

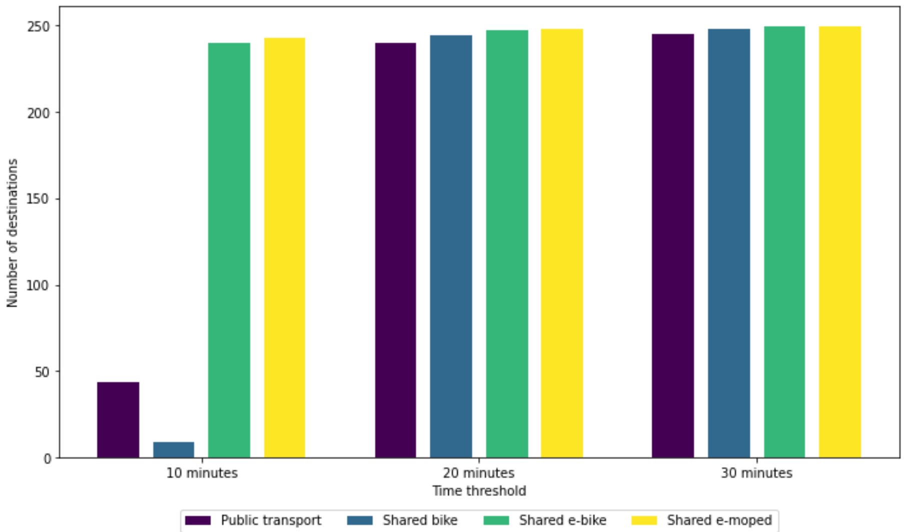


Figure 33: Accessible destinations from P+R Deutersestraat for time thresholds

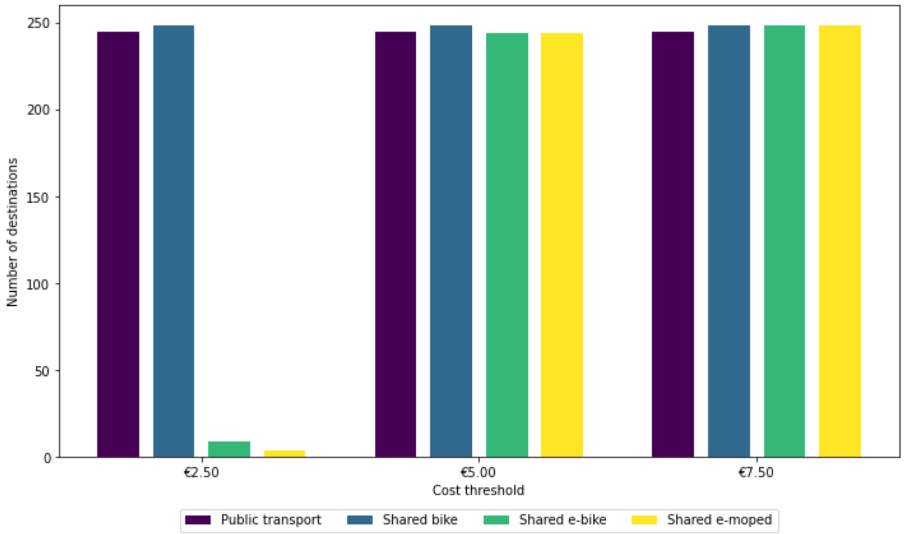


Figure 34: Accessible destinations from P+R Deutersestraat for cost thresholds

POI

The accessible POI are visualised in Figure 35 and Figure 36 for P+R Deutersestraat. Figure 35 shows that the shared modes have higher accessibility than public transport for the time thresholds. The service areas in Figure 37 illustrate the accessibility of the different modes. This corresponds with previous research of Nichols et al. (2023) that also found that more amenities can be reached with a shared bike than with public transport. For the cost thresholds, Figure 36 shows that the shared bike has the highest accessibility for all thresholds. For the lowest cost threshold, public transport has higher accessibility than a shared e-bike and shared e-moped. When the cost threshold increases, all three shared modes can reach more POI than public transport, as is also visible in Figure 37. Previous research comparing the accessibility of shared modes for a cost threshold of €4.45 also found a higher accessibility for a shared e-bike than for a shared e-moped (UUM, 2023).

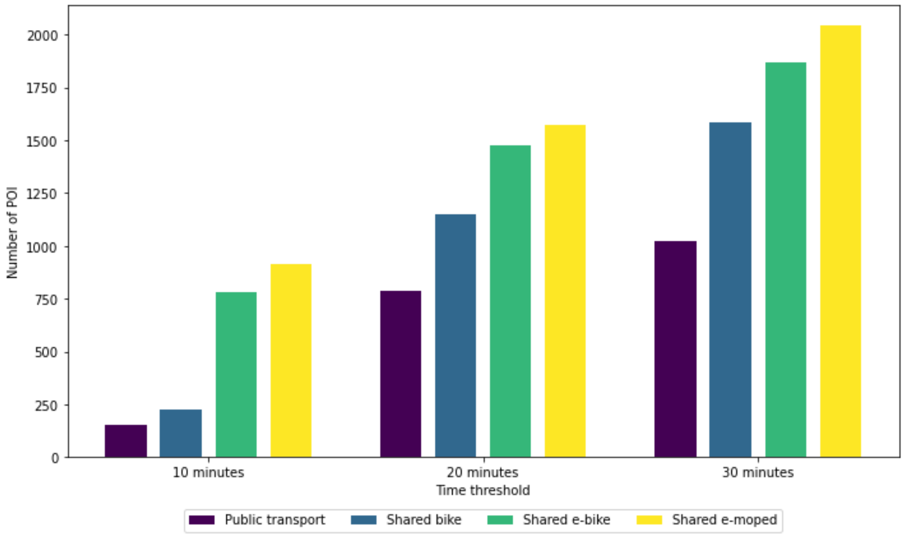


Figure 35: Accessible POI from P+R Deutersestraat for time thresholds

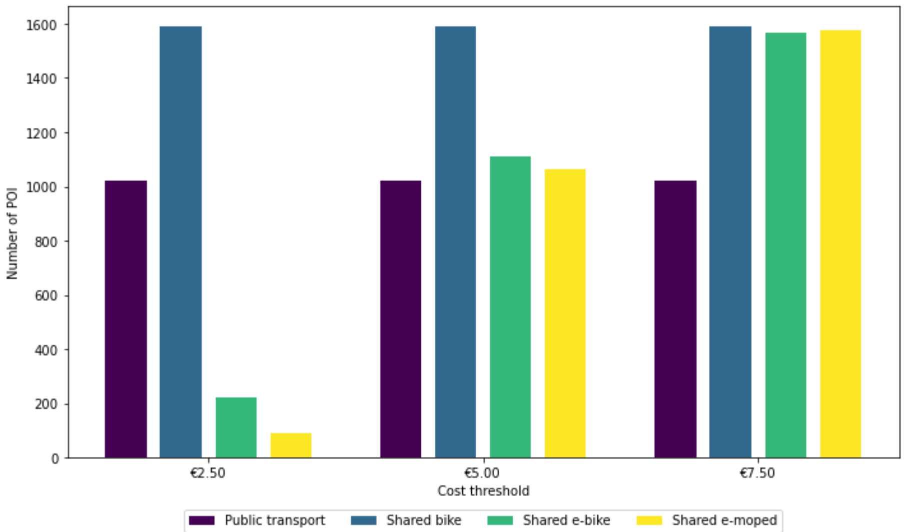
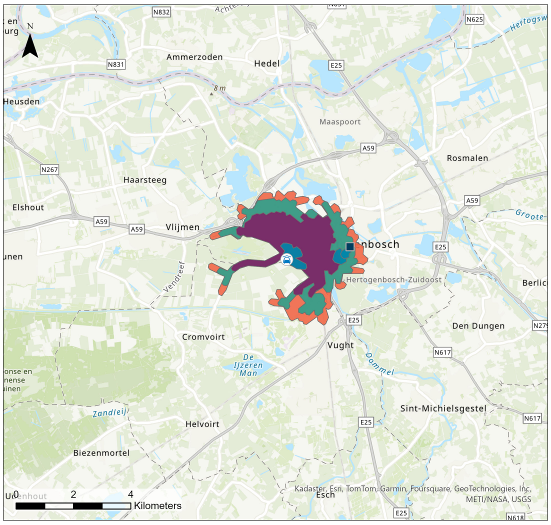
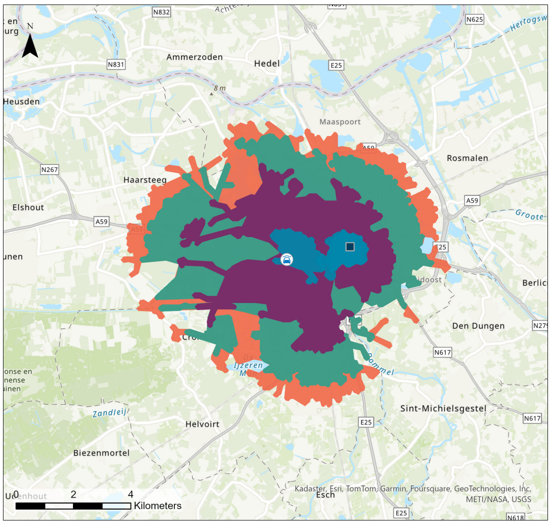


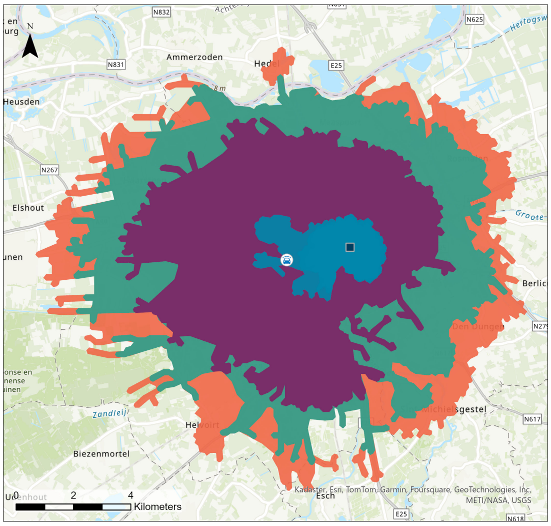
Figure 36: Accessible POI from P+R Deutersestraat for cost thresholds



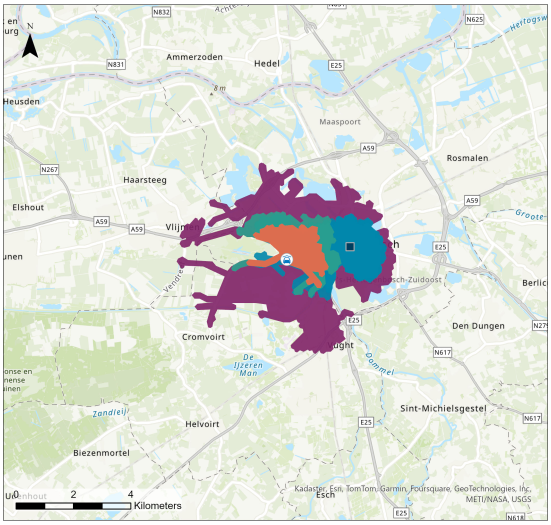
(a) Time threshold: 10 minutes



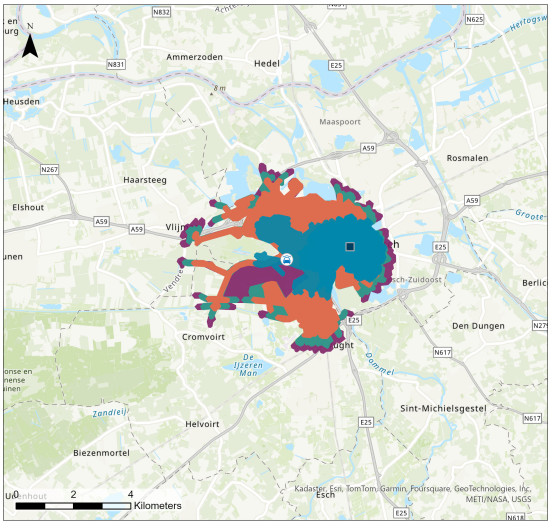
(b) Time threshold: 20 minutes



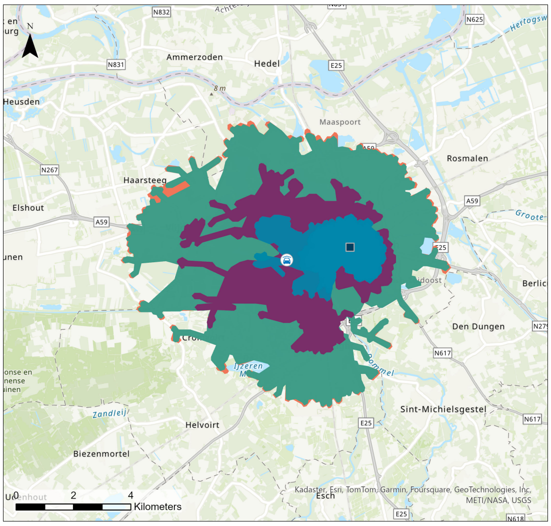
(c) Time threshold: 30 minutes



(d) Cost threshold: €2.50



(e) Cost threshold: €5.00



(f) Cost threshold: €7.50

Legend	Public transport	(blue)	Shared bike	(purple)	Shared e-bike	(green)	Shared e-moped	(orange)
	P+R	(P+R icon)	City centre	(dark square)				

Figure 37: Service areas for P+R Deutersestraat

5.4.3 Summary

The accessibility analysis of this study was aimed at answering the fourth research question: *What is the difference in accessibility between shared mobility and public transport as last-mile transportation modes at a P+R location, considering cost and time thresholds?*

Table 17 summarizes the accessibility analyses for the two locations. It indicates for the time and cost thresholds which mode has the best accessibility at one of the locations expressed in the number of destinations reached or the number of POI reached. For example, "Deu[a,b]" for the shared e-moped and the 10-minute time threshold indicates that for P+R Deutersestraat the best accessibility expressed in the number of destinations and the number of POI that can be reached with the shared e-moped (compared to the other three modes). The table shows that for the same time threshold, the shared e-bike can reach (almost) equal accessibility expressed in the number of destinations that can be reached from P+R Deutersestraat (indicated with "Deu[a]" in the table).

What can be deduced from the bar charts in section 5.4.1, is that the accessibility for the 10-minute threshold is low for P+R Maastricht Noord. It implies that most destinations of respondents and POI are located in the city centre, which is more than 10 minutes of travelling for any last-mile mode. When comparing that with the bar charts for the 10-minute threshold of P+R Deutersestraat (section 5.4.2), better accessibility is shown mainly for the shared e-bike and shared e-moped. As is summarized in Table 17, this implies that in case the P+R is located relatively close to the city centre, a shared e-bike or shared e-moped results in the best accessibility. This corresponds with previous research of Nichols et al. (2023) that also found better accessibility for shared mobility compared to public transport.

When expressing the accessibility in the number of POI that can be reached for a certain time threshold, the table shows that for both P+R locations the shared e-moped has the best accessibility. However, comparing this with the accessibility of POI considering the cost thresholds it shows that using a shared e-moped is more expensive than other modes. For cost thresholds €2.50 and €5.00, one can access the most POI when using a shared bike and only at P+R Deutersestraat does the e-moped has the best accessibility for the €7.50 threshold. A previous study of UUM (2023) that conducted accessibility analyses for a time and cost threshold also found that there are large accessibility differences between the type of threshold considered for a shared mode.

Comparing the different modes for the cost thresholds, it can be seen that the price scheme of a shared mode influences accessibility. The table shows that the shared bike has at both locations a better price scheme for high accessibility compared to a shared e-bike or shared e-moped. The shared bike system at P+R Deutersestraat has a fixed price (so not dependent on travel time or distance) and the system in Maastricht is relatively cheap (first 20 minutes for €1.00, afterwards €0.01 per minute). Compared to the prices of using a shared e-bike or shared e-moped which have prices of respectively €0.26 and €0.33 per minute, this results in a relatively large accessibility difference. Despite that your travel takes longer when using a shared bike, compared to a shared e-bike or shared e-moped, it can be the cheapest option and you can reach more destinations than with public transport.

To summarize, public transport mainly results in the best accessibility for the lowest time or cost threshold compared to shared micromobility. For the other time thresholds, one could access more destinations or POI with shared micromobility according to this analysis. However, the analyses for the cost thresholds show that especially for a shared micromobility system which applies a price schedule where the price increases for every minute you travel, public transport or a fixed-price system can be a cheaper option. Besides, external reasons for the choice of transport mode are not yet included in this analysis, such as weather conditions or travel motives (e.g. having lots of luggage when going shopping). Although travel time and travel cost were not identified as significant factors in the regression analysis, the accessibility analysis shows that the accessibility differences between modes can be large and the accessibility for cost and time thresholds are different.

Table 17: Summary table indicating per threshold which shared mode has the best accessibility for P+R Maastricht Noord (Ma) and P+R Deutersestraat (Deu)

	Public transport	**Shared bike**	**Shared e-bike**	**Shared e-moped**
Time threshold				
10 minutes	Ma[a]	Ma[a]	Deu[a], Ma[a]	Deu[a,b], Ma[a,b]
20 minutes	Deu[a]	Deu[a]	Deu[a], Ma[a]	Deu[a,b], Ma[a,b]
30 minutes	Deu[a]	Deu[a], Ma[a]	Deu[a], Ma[a]	Deu[a,b], Ma[a,b]
Cost threshold				
€2.50	Deu[a]	Deu[a,b], Ma[a,b]		
€5.00	Deu[a]	Deu[a,b], Ma[a,b]	Deu[a]	Deu[a]
€7.50	Deu[a]	Deu[a], Ma[a,b]	Deu[a,b]	Deu[a,b]

[a] Accessibility expressed in number of destinations that can be reached for certain threshold
[b] Accessibility expressed in number of POI that can be reached for certain threshold

6 Discussion

This section discusses the results, along with the limitations of certain methodological decisions. First, the importance of travel time and cost as factors influencing mode choice are discussed. The next section elaborates on the role of shared micromobility at a P+R. Furthermore, the suitability of shared micromobility systems is discussed. Finally, before discussing the research limitations, the role of flanking policies is explained.

6.1 Importance of travel time and cost

The literature review on user- and transportation characteristics influencing mode choice describes travel time and travel cost as two important factors (De Witte et al., 2013; KiM, 2021a; Van Veldhoven et al., 2022). Both factors are considered in the accessibility analysis as thresholds, to compare the accessibility of public transport and the shared modes. With the service areas drawn as shown in Figure 32 and 37, it is a nice visual way of comparing transportation modes. Travel time and cost were both considered as trip characteristics in the regression analyses, but for none of the dependent variables, the factors were found to be significant. Therefore, one could question to what extent this information is important in relation to the significant predictors for the intended use of shared micromobility.

The motivators for using shared micromobility give more insight into what travellers value as important. Figure 17 shows the motivators for using public transport or a shared bike as a last-mile transportation mode. It was found that affordability is the most chosen motivator for public transport users. For shared bike users, the main motivator is that it is a quick way of travelling to the destination. This illustrates that based on the motivators, travel time and cost are important factors to consider in analysing the potential of shared micromobility at a P+R location. It substantiates the research method that is applied for analysing the potential of shared micromobility at P+R locations. This means that conducting an accessibility analysis based on travel time and cost is important in addition to studying user characteristics and other influential factors for the use of shared micromobility.

To gain more understanding of the importance of trip characteristics such as travel time and cost, conducting a stated preference experiment could be of added value for further research. Due to the limited time for conducting this research, it was decided not to include a stated preference experiment in the survey. A stated preference experiment was for example part of the SmartHubs research (Gkavra et al., 2024). This experiment aims to understand people's willingness to shift to a mobility hub-based mode in case public transport and three different sharing services were available (bikes, e-scooters, cars) at a mobility hub.

6.2 Shared micromobility complementary to public transport

The results of the accessibility analysis for time thresholds show that for both locations shared micromobility has better accessibility than public transport, with the best accessibility for the shared e-moped. This shows that there is potential for shared micromobility at a P+R location. Yet the majority of respondents (65.6%) indicate that they have no intentions to use shared micromobility, as also shown in the Sankey diagram of Figure 19. The significant factors and the accessibility analysis for the cost thresholds give a reason why shared micromobility should be offered complimentary to public transport rather than as a substitute.

The regression analysis found walking difficulty as a significant predictor. People with walking difficulty have a lower intention to use a shared bike. Because of their mobility limitations, they might not be able to use a shared mode at all. Maintaining the public transport connection is therefore important to retain this target group at the P+R. Besides, the ability to use a shared e-moped was found as a significant independent variable for the intended use. People who do not know if they have the ability to use a shared e-moped have lower intentions of using it. Not knowing how to use a shared e-moped, is an important barrier for people as well. This corresponds with the barriers for the non-intended users of shared micromobility shown in Figure 21. A large proportion of the respondents also indicate that they do not want to use shared micromobility as they do not know how to use it.

Where the accessibility analysis for the time thresholds shows better accessibility for shared micromobility than for public transport, the accessibility analysis for the cost thresholds shows a different pattern. Figure 31 and 36 clearly show that for a cost threshold of €2.50 public transport has a better accessibility than the shared e-bike and e-moped. Although travel costs are not found to be a significant predictor, it is likely that if the cost difference between public transport and shared micromobility is large, people would prefer public transport. Previous research into the intention to use shared mobility for vulnerable to exclusion groups by Garritsen et al. (2024) described that costs are mainly an important barrier for low-income groups.

6.3 Type of shared micromobility system

Section 2.3 of the literature review describes that there are currently various shared micromobility systems. It describes that for shared bikes this is mostly a station-based system, where a user picks up and returns the bike at the same location. The price for using the bike is not linked to the distance or travel time they travel. At P+R Deutersestraat, a roundtrip shared bike system is currently present. For shared e-bikes and e-mopeds, this is often a free-floating system, where people can pick up a shared mode close to their origin and leave it close to their destination. The price of using a mode is linked to the travel time or distance in the case of a free-floating system. At P+R Maastricht Noord, a one-way shared bike system is present, as there are multiple fixed locations where a shared bike can be picked up or returned. The results of this research give some insight into what type of system is desired at a P+R location.

First, looking at the travel costs for using both systems, a roundtrip system is in most cases cheaper than a free-floating system. For example, using an OV-fiets costs currently €4.55 per day (NS, 2024a). Comparing this with a shared e-bike of GO Sharing (2024) with a price of €0.26 per minute, someone can only travel 17.5 minutes with a shared e-bike for the same price. This shows that for trips longer than 17.5 minutes, using a roundtrip system such as the OV-fiets is cheaper.

The regression analysis shows that the availability of transport modes is a significant predictor of the intention to use a shared bike. Someone who values this characteristic as important has a higher intention to use a shared bike. So this is an important characteristic to consider when facilitating shared micromobility at a P+R location. Previous research also describes that unavailability is a barrier that could limit the adoption of bike sharing (KiM, 2021a). For free-floating systems, there is a risk of unavailability both at the pick-up location and at the destination location, as the mode can be used by other users when someone has finished their trip. Therefore, a roundtrip system in combination with real-time information on the availability of the shared modes might be the most desirable to facilitate at a P+R location, to prevent unavailability of the shared mode at both origin and destination.

Related to the type of shared micromobility system is also the payment method which differs per system. A free-floating system works with an app to unlock the shared mode and to pay for the trip. As for a roundtrip system someone pays a set price, the payment can also be done on beforehand as is done at P+R Deutersestraat by including bike usage in the P+R tariff. Besides, the OV-fiets system only requires an OV-chipkaart with a free subscription to use the bike. The regression analysis showed that someone who values payment methods at the P+R location as important has a significantly higher intention to use a shared e-bike. This implies that providing multiple payment options might be positive for shared e-bike usage. Previous research also indicates that the type of payment system is an important motivator for using a bike-sharing system (Ma et al., 2020). Having a system that requires the use of an app might also exclude P+R users who are less digitally skilled. Focusing on the payment systems, a roundtrip system seems therefore to be more suitable for a P+R location.

6.4 The role of flanking policies

The potential of shared micromobility at a P+R location also depends on flanking policies related to the P+R itself and how shared micromobility is integrated into the mobility system of a city, as was described in a previous study of Rongen et al. (2022). This study mentions three factors that influence the effectiveness of hub concepts. First, the price of the P+R location in relation to the prices of city centre parking. When people can park relatively cheaply in the city centre, a P+R location is likely less used. The same holds when the P+R tariff is relatively high in comparison to the city centre parking fares. Second, if the city centre has sufficient price-competitive parking capacity, people are not tempted to drive with the car straight to their destination. Finally, the integration of the P+R location into the public transport network of a city. When the travel time difference of driving directly to the destination with a car or travelling via the P+R is too large, the latter option is less attractive for people. These factors all depend on flanking policies that influence the effectiveness of the P+R location.

A suggestion of a flanking policy that could stimulate the use of shared micromobility at a P+R location, is the inclusion of travelling with a shared mode into the P+R tariff. For most P+R locations in the Netherlands, people pay for parking and a public transport trip. Using a shared mode is often not included in the price, for example at the peripheral P+R locations where an OV-fiets is present. P+R Deutersestraat is an exception compared to most locations, as using a shared bike is included in the P+R tariff. When people have the choice to use a shared mode for the same price as they would use public transport, this might be more attractive. In addition to that people must be well-informed about their last-mile possibilities, as at P+R Deutersestaat no clear on-site information was present about the availability of the shared bikes.

6.5 Research limitations

When considering the results of this research, it is important to keep in mind some limitations that were faced. These research limitations relate to the data that is used, the survey that is distributed and how they are interpreted, the characteristics of the survey sample and some limitations in conducting a regression analysis.

6.5.1 Data

For the first research question, the current presence of shared mobility at peripheral P+R locations in the Netherlands was studied. The Dashboard Deelmobiliteit of the CROW (2024a) provides real-time information on the location of various shared modes. However, experts of Royal HaskoningDHV who work with this data noticed that sometimes the dashboard is not correctly updated, so the information could be outdated. Besides, only the actual location of free-floating shared mobility services was presented and there was no information available about the locations of shared modes in the past. Therefore, the presence of shared modes at P+R locations could differ in reality from the information found for the spatial analysis.

Part of the accessibility analysis was to create a network dataset in ArcGIS Pro to generate service areas. For the public transit network, GTFS data can be used to create this network dataset. However, during the creation of the network dataset it was experienced that the data did not show the expected results. Therefore, walking service areas were manually generated based on the bus schedules from Arriva (2024c) as was previously explained in section 4.4. Although the current method corresponds to the working of the network analysis tool with GTFS data, in reality, different service areas may be generated.

6.5.2 Survey development and distribution

The survey that was distributed for this research was developed by the researcher himself, using surveys of previous studies such as the SmartHubs research (Gkavra et al., 2024). The open-source survey application LimeSurvey was used to develop the survey, as the research group of the University of Twente uses this platform. Before distributing the survey, the questions were shared with the privacy representative of the faculty of Engineering Technology as this study contains personal data. Despite the survey being anonymous, some questions had to be removed (e.g. the question asking the household income and the home location) to distribute the survey without additional GDPR requirements. Since removing these questions would not make the study aim impossible, it is not a major problem to the research outcome.

A digital survey was developed, which people could fill in on their mobile phones or other devices with an internet connection. At the P+R locations, a flyer with a QR code was distributed to the P+R users (see also Appendix A) so people could scan the QR code and fill in the survey directly. For users of the P+R Maastricht Noord, the survey was also distributed among the mobility panel, in the newsletter and on the website of Maastricht Bereikbaar. Since no paper version of the survey was available and the survey was only in Dutch, mainly older people without a smartphone and foreign people that do not speak Dutch were little to not included in the survey sample. However, only a small number of P+R users indicated to the researcher that they could not complete the survey for one of these reasons. Nevertheless, this might be an explanation for the small number of people who have a low digital skills level and the small group of people with a non-Dutch background.

The survey is distributed at two peripheral P+R locations: P+R Maastricht Noord and P+R Deutersestraat in 's-Hertogenbosch. As is illustrated by the spatial analysis of P+R locations, every P+R location has a different public transport connection and is located differently towards the city centre which influences travel times and has shared modes available or not. Therefore, the outcome of this research could be different when the survey is distributed at other P+R locations. This should be considered when interpreting the results of the research. Furthermore, as the researcher distributed the flyers alone some users of the shared bikes in P+R Deutersestraat were not approached as the bicycle parking was located too far away from the location of the researcher. The current use of the shared bikes in 's-Hertogenbosch might therefore be a bit higher. Finally, the survey was distributed for three weeks in March 2024. During this period the outside temperature varied between 5 and 14 degrees including two days with rain. As indicated by previous research, weather circumstances influence the intention of people to choose shared mobility, so with different weather circumstances the outcome might be influenced (Jonkeren, 2020; van Marsbergen et al., 2022).

6.5.3 Survey interpretation of respondents

Going through the survey results, also some non-expected observations were found. One of the questions was on the current last-mile transportation mode. Checking the survey results after the first day of survey distribution, 11 people indicated using a private transportation mode to travel the last mile. However, it was observed that every P+R user who was approached with a flyer used the bus to continue their journey. The formulation of the question was modified to prevent this from happening again, but it cannot be excluded.

Another question asked the destination of the respondents. They could fill in a 4-digit postal code or the name of the location. For the descriptive statistics and the regression analysis, the locations were mapped and based on the shortest path the distance between the P+R and destination locations were determined. It was noticed that some respondents indicated a location far away from the P+R, even up to more than 200 kilometres away. One explanation could be that the question was misinterpreted and respondents filled in their origin location, as they returned to that location after visiting the destination in 's-Hertogenbosch or Maastricht. This misinterpretation could also influence other questions, as it is not likely that people have the intention to use shared mobility from the P+R to their home location as that might be a too large travel distance. Another explanation might be that the further away indicated destinations are correct and that people use the P+R as a remote P+R, so that they travel the main part of their journey with public transport. As P+R Maastricht Noord has also a train connection towards Kerkrade, this is a likely option.

A final survey interpretation limitation relates to the trip characteristics. The respondents were asked to indicate how important they value certain trip characteristics (e.g. travel costs or facilities at the P+R) in the choice for a last-mile transportation mode. As shown in Appendix B, an array answer type was used when setting up the survey so respondents could easily answer for each characteristic how important they think it is. However, this answer type is sensitive to straight-lining which is a small limitation of this survey. A suggestion to prevent straight-lining could be to add a question for quality purposes, asking for example respondents to select a specific answer option from a set of options (e.g. select number 10 from four answer options). This was done in the audience survey of the Pinkpop festival.

6.5.4 Sample characteristics

The sample characteristics are discussed in section 5.2.1 of this report. As the P+R users do not originate from a specific municipality or region, it is difficult to select a representative sample to compare the survey sample with. Therefore, multimodal travellers (Car + PT) from the ODiN-research were selected as the population sample for this study. It was chosen to only include data from 2019 and 2022, to have recent data from a period outside the COVID-19 pandemic. However, this resulted in a small sample size of the population sample group of N=125 for Maastricht and N=156 for 's-Hertogenbosch. This should therefore be kept in mind when the sample characteristics of the survey are compared with the population sample. As the aim of the study is to analyse significant independent variables of the intended use of shared micromobility, and not to make predictions of shared micromobility use at a P+R, it is expected not to be a major limitation for this study.

6.5.5 Regression analysis

Performing a regression analysis also entails certain limitations. A variety of user- and transportation characteristics are included as well as the bikeability index as a built environment factor. In the literature review, it was found that built environment characteristics can also influence the intention to use a certain transportation mode. The bikeability index only assesses the built environment on the quality of the bicycle infrastructure. However, including more built environment characteristics such as land use type and degree of urbanisation might result in a significant built environment predictor which was not the case in this study.

Section 5.3.1 explains that multiple regression models are run with different settings to determine the most suitable model. It is explained that for the fourth model run, all destinations with a destination further away than 7 kilometres from the P+R were given a missing value for the bikeability index, and were thus excluded from the model. Looking into the significant variables of this model, the distance is a significant independent variable for the intention to use a shared bike or shared e-bike. The relation between the distance variables describes that the intention to use a shared bike or shared e-bike decreases when the travel distance increases. This finding is in line with the previous assumption for the selection of P+R locations, that when a P+R location is located further away from the city centre shared mobility is not an attractive alternative for users.

7 Conclusion and Recommendations

This research investigated the potential of shared micromobility at peripheral P+R locations in the Netherlands, by studying the intention to use shared micromobility as a last-mile transportation option and analysing the accessibility of public transport and shared micromobility. Currently, at 77% of the peripheral P+R locations, at least one shared mode type is available. Furthermore, for 51% of the peripheral P+R locations with at least one shared mode, using the available shared mode is faster to reach the city centre than public transport. This implies that there is potential for shared micromobility at P+R locations, as travel time is generally an important factor that people consider for mode choice. However, there are more factors that influence the intention to use shared micromobility. By means of a multi-criteria analysis using the information of the spatial analysis, two study locations were chosen to distribute a survey: P+R Maastricht Noord and P+R Deutersestraat ('s-Hertogenbosch).

The survey provided insight into the characteristics of the P+R users and which factors influence the intention to use shared micromobility at a peripheral P+R location. The sample characteristics of the survey sample indicate that both locations are used by a greater proportion of female respondents, older respondents and part-time employed respondents compared to a population sample. Shared bikes are present at both study locations, but are only used by 1.9% of the sample as the majority use the bus to travel the last mile. However, the survey results show that the intention of P+R users to use shared micromobility is higher. From the current public transport users (N=631), 34.4% intend to use at least one of the shared modes (i.e. shared bike, shared e-bike, shared e-moped) when public transport is not available at the P+R location. This proportion of the intended users implies that current P+R users are willing to use shared micromobility.

The regression analysis gave insight into the characteristics that significantly influence the intention to use shared micromobility. It provides also insight into significant characteristics of the group that has no intention to use shared micromobility, which is the majority of the survey sample. It was found that people with a walking ability have a lower intention to use a shared bike, and a significantly lower intention was found for a group that does not know if they are able to use a shared e-moped. This illustrates that for a part of the P+R users, the public transport connection is important as they are unlikely to use shared micromobility due to their physical abilities. Three trip characteristics were found to be significant predictors for the intention to use shared micromobility, and are therefore important aspects to consider when facilitating shared micromobilty at P+R locations. Someone who values payment methods at a P+R location as important for mode choice has a higher intention to use a shared e-bike. Besides, it was found that the availability of a transport mode is a significant predictor of the intention to use a shared bike. These factors imply that the type of shared micromobility system, roundtrip or free-floating, and type of payment method, via an app or providing multiple payment options, have an influence on the intended shared mobility usage. In addition, the facilities at a P+R location are a significant predictor for the intention to use a shared e-moped, which implies that further development of a P+R with other facilities can also have a positive effect on the potential for shared micromobility at P+R locations, which was described by Kwantes and Scheltes (2021). Finally, the regression analysis confirms that prior shared mobility experience positively influences the intention to use shared micromobility, and younger age groups have a higher intention to use a shared e-moped.

As the spatial analysis revealed, shared micromobility can be a faster alternative to public transport for peripheral P+R locations. The accessibility analysis analysed the differences in accessibility between public transport and shared micromobility for time and cost thresholds. The analysis for the time thresholds confirms for the study locations the finding of the spatial analysis, that shared micromobility has a better accessibility than public transport expressed in POI. The accessibility analysis for the cost thresholds shows that for a cost threshold of €2.50 public transport has better accessibility, as the price for using shared micromobility is higher. Travelling with public transport from the P+R to the destination is currently often included in the P+R tariff, but not for shared micromobility. Adding shared micromobility as an extra last-mile travel option for the same P+R tariff as travelling with public transport can be a good policy measure, as is already done at P+R Deutersestraat.

Overall, given the methodology used in this study, the analysis of the survey and the accessibility analysis show that there is potential for shared micromobility at peripheral P+R locations. This study shows that further development of a P+R location to transfer hubs with shared micromobility can be a promising measure, as was also described by the studies of Kwantes and Scheltes (2021) and Rongen et al. (2022). Considering the influential factors that are found in this study can help to develop and facilitate a shared micromobility system that suits most to the potential user. Besides, maintaining the public transport connection at the P+R location is important to facilitate a group of current P+R users, such as users with mobility impairments.

7.1 Recommendations

Based on the findings of this research, some recommendations can be made for further research and what is important to consider in practice for future P+R development projects. Starting with recommendations for further research. The regression analysis showed that people who value facilities at a P+R location have a significantly higher intention to use a shared e-moped. This finding is in line with the studies of Kwantes and Scheltes (2021) and Rongen et al. (2022) that describe that adding extra facilities is a promising measure. For further research, it is interesting to study what type of facilities would be positive for the use of a P+R location and shared micromobility as a last-mile transportation mode. A stated preference experiment could be used to investigate this. Besides, this research only studies the intention to use shared micromobility among the current P+R users as that is the target group of the survey. It would be interesting to also study if shared micromobility and other facilities would attract new users. Therefore, distributing a survey at parking hot spots in a city could be a valuable addition to this research. A final recommendation for further research is to study what type of shared micromobility system is the most desirable for P+R location. This research showed interesting differences between a roundtrip system and a free-floating system in the accessibility analysis, and the regression analysis found significant trip characteristics that are related to the type of system. Conducting additional survey research into what type of system users want can help to provide more insight.

Next to the recommendations for further research, also some recommendations for future P+R development projects can be made. This research shows that conducting an accessibility analysis for both time and cost thresholds is a nice way to visually compare the different last-mile transportation modes. This is for example a nice method to present results to people who are not mobility experts, like policy makers at a municipality. For this study, it was chosen to express the accessibility in the number of destinations and the number of POI, but other measures could also be used such as the number of jobs. Besides, the accessibility analysis for the cost threshold shows that shared micromobility is for many trips less attractive than public transport as it is more expensive. Going into consultation with shared micromobility providers to integrate the use of a shared mode into the P+R tariff, as is currently the case for public transport, can help to make it a more attractive last-mile transportation mode to use. Finally, the sample characteristics of our survey sample showed that the P+R user is older than the majority of the current shared micromobility users in the Netherlands. This is important to consider when facilitating a shared micromobility system at a P+R, as the development and integration of the system at a P+R might need a different approach than for example at neighbourhood hubs in a city.

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A Flyer for survey distribution

Figure 38: Flyer used for the distribution of the survey at the P+R locations

B Full survey

1. Introduction				
ID	**Question**	**Answer type**	**Answer set**	**Routing**
Welkomstekst	Beste P+R gebruiker, Hartelijk dank voor uw deelname aan deze enquête! De enquête is onderdeel van een afstudeeronderzoek naar het reisgedrag van Park and Ride (P+R) gebruikers naar hun bestemming. Dit onderzoek wordt uitgevoegd in samenwerking met Royal HaskoningDHV. • De enquête duurt ongeveer 5 tot 10 minuten. • De enquête bevat 29 vragen. • Vragen met een * zijn verplicht om in te vullen. Voor vragen over het onderzoek of de enquête kunt u contact opnemen met Tom van Hal (t.a.j.vanhal@student.utwente.nl). UNIVERSITY OF TWENTE. Royal HaskoningDHV Enhancing Society Together			
Toestemming	**Toestemming:** • Uw deelname is vrijwillig. • U bent niet verplicht om deel te nemen en indien u weigert, heeft dit geen gevolgen voor u. • Na het starten van de enquête kunt u op elk moment stoppen. • De gegevens die verzameld worden met deze enquête worden uitsluitend gebruikt voor doeleinden van dit afstudeeronderzoek.	Select one	○ Hierbij bevestig ik dat mijn deelname aan dit onderzoek volledig vrijwillig is, dat ik juist ben geïnformeerd over het doel van de studie en dat ik om welke reden dan ook mijn deelname aan deze vragenlijst kan beëindigen.	
PRLocatie	Kies uw P+R locatie.	Select one	○ P+R Maastricht Noord ○ P+R Deutersestraat ('s-Hertogenbosch)	

2. Travel behaviour – Explanation shared mobility				
ID	**Question**	**Answer type**	**Answer set**	**Routing**
RGMaastricht	In de enquête zullen een aantal vragen gaan over deelmobiliteit. De volgende deelvervoermiddelen worden onderscheiden: **Deelfiets**, zoals OV-fiets of Arriva-deelfiets   **Elektrische deelfiets**, zoals Bolt- of TIER-fiets  **Deelscooter,** zoals Go-Sharing, Felyx of Check-scooter  **Deelauto**, zoals Greenwheels of MyWheels-auto 			PRLocatie → P+R Maastricht Noord

<table>
<tr><td>RGDenBosch</td><td>In de enquête zullen een aantal vragen gaan over deelmobiliteit. De volgende deelvervoermiddelen worden onderscheiden:

Deelfiets, zoals OV-fiets of Transferium Leenfiets
 
Elektrische deelfiets, zoals Bolt- of TIER-fiets

Deelscooter, zoals Go-Sharing, Felyx of Check-scooter

Deelauto, zoals Greenwheels of MyWheels-auto
</td><td>PRLocatie → P+R Deutersestraat</td></tr>
</table>

<table>
<tr><th colspan="5">3. Travel behaviour - General</th></tr>
<tr><th>ID</th><th>Question</th><th>Answer type</th><th>Answer options</th><th>Routing</th></tr>
<tr><td>Vervoerswijzen</td><td>Hoe vaak hebt u het afgelopen jaar de volgende vervoerswijzen gebruikt?</td><td>Matrix table</td><td>
<table>
<tr><th></th><th>4 of meer dagen per week</th><th>1-3 dagen per week</th><th>1-3 dagen per maand</th><th>6-11 dagen per jaar</th><th>1-5 dagen per jaar</th><th>Nooit</th></tr>
<tr><td>Openbaar vervoer (bus/tram/metro/trein)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelfiets (bijv. OV-fiets)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elektrische deelfiets (bijv. Bolt, TIER)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelscooter (bijv. Go-Sharing, Felyx, Check)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelauto (bijv. Greenwheels, MyWheels)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>FysiekLopen</td><td>Is het voor u moeilijk om langer dan 15 minuten te lopen?</td><td>Select one</td><td>o Ja
o Nee
o Nee, maar ik gebruik wel een hulpmiddel (bijv. rolstoel of rollator)</td><td></td></tr>
<tr><td>FysiekFietsen</td><td>Bent u fysiek in staat om te fietsen</td><td>Select one</td><td>o Ja
o Nee
o Weet ik niet/Nooit geprobeerd</td><td>Vervoerswijzen: Deelfiets → Nooit</td></tr>
</table>

3. Travel behaviour - General				
ID	**Question**	**Answer type**	**Answer options**	**Routing**
FysiekScooter	Bent u fysiek in staat om met een scooter te rijden?	Select one	o Ja o Nee o Weet ik niet/Nooit geprobeerd	Vervoerswijzen: Deelscooter → Nooit

4. Travel behaviour – P+R				
ID	**Question**	**Answer type**	**Answer set**	**Routing**
PRVragen	De volgende vragen van deze enquête gaan over reizen van **[P+R Maastricht Noord/P+R Deutersestraat] naar uw bestemming**.			
PRFreqGebruik	Hoe vaak hebt u in het afgelopen jaar gebruik gemaakt van [P+R Maastricht Noord/P+R Deutersestraat]?	Select one	o 4 of meer dagen per week o 1-3 dagen per week o 1-3 dagen per maandag o 6-11 dagen per jaar o 1-5 dagen per jaar o Dit is de eerste keer	
PRVervoerMaastricht	Welke van de onderstaande vervoersmiddelen heeft u tijdens uw laatste reis gebruikt om **van** P+R Maastricht Noord **naar** uw eindbestemming (bijv. stadscentrum of werk) te gaan?	Select one	o Bus o Trein o Deelfiets (OV-fiets of Arriva-deelfiets) o Eigen vervoer (bijv. fiets) o Lopend o Anders, namelijk: …	PRLocatie → P+R Maastricht Noord
PRVervoerDenBosch	Welke van de onderstaande vervoersmiddelen heeft u tijdens uw laatste reis gebruikt om **van** P+R Deutersestraat **naar** uw eindbestemming (bijv. stadscentrum of werk) te gaan?	Select one; text	o Bus o Deelfiets (Transferium leenfiets) o Eigen vervoer (bijv. fiets) o Lopend o Anders, namelijk: …	PRLocatie → P+R Deutersestraat
Reden	Wat zijn de belangrijkste redenen waarom u met dit vervoersmiddel hebt gereisd?	Multiple choice; text	☐ Het is betaalbaar ☐ Het is snel ☐ Het is comfortabel ☐ Het is veilig ☐ Het is goed voor mijn gezondheid ☐ Het is duurzaam ☐ Het is flexibel ☐ Het is betrouwbaar ☐ Anders, namelijk: …	

4. Travel behaviour – P+R				
ID	**Question**	**Answer type**	**Answer set**	**Routing**
Reismotief	Wat is uw belangrijkste reismotief van uw laatste reis vanaf [P+R Maastricht Noord/P+R Deutersetraat]?	Select one	o Van en naar het werk o Winkelen, boodschappen doen o Diensten/verzorging o Onderwijs volgen, cursus, kinderopvang o Bezoeken van familie of vrienden o Sport, hobby, horecabezoek o Toeren/wandelen o Anders, namelijk: …	
Reisgezelschap	Reisde u alleen of met anderen tijdens uw laatste reis vanaf [P+R Maastricht Noord/P+R Deutersestraat]?	Select one	o Ik reisde alleen o Ik reisde met een ander persoon o Ik reisde met twee of meer andere personen	
Reistijd	Wat is uw reistijd (in minuten) van [P+R Maastricht Noord/P+R Deutersestraat] naar uw eindbestemming van uw laatste reis?	Text	…	
Bestemming	Wat zijn de vier cijfers van de postcode van de eindbestemming van uw laatste reis vanaf [P+R Maastricht Noord/P+R Deutersestraat]? (Bijv. 1234) Wanneer u dit niet weet kunt u de naam van de locatie van bestemming invullen (bijv. de straatnaam of stadscentrum)	Text	☐ Postcode: … ☐ Locatie (bijv. naam van locatie of stadscentrum): …	

<table>
<tr><th>ID</th><th>Question</th><th>Answer type</th><th>Answer set</th><th>Routing</th></tr>
<tr><td>AlternatiefOV</td><td>Wanneer [PRVervoerMaastricht/PRVervoerDenBosch] niet beschikbaar is, hoe waarschijnlijk is het dat u een van onderstaande vervoersmiddelen zou gebruiken om van [P+R Maastricht Noord/P+R Deutersestraat] naar uw eindbestemming te reizen?

Ga ervan uit dat onderstaande vervoersmiddelen wel aanwezig zijn op de P+R.</td><td>Matrix table</td><td>
<table>
<tr><th></th><th>Zeer onwaarschijnlijk</th><th>Onwaarschijnlijk</th><th>Neutraal</th><th>Waarschijnlijk</th><th>Zeer waarschijnlijk</th></tr>
<tr><td>Deelfiets (bijv. OV-fiets)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elektrische deelfiets (bijv. Bolt, TIER)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelscooter (bijv. Go-Sharing, Felyx, Check</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>PRVervoerMaastricht → Bus OF Trein
PRVervoerDenBosch → Bus</td></tr>
</table>

<table>
<tr><th>ID</th><th>Question</th><th>Answer type</th><th>Answer set</th><th>Routing</th></tr>
<tr><td>AlternatiefDeelfiets</td><td>Wanneer [PRVervoerMaastricht/PRVervoerDenBosch] niet beschikbaar is, hoe waarschijnlijk is het dat u een van onderstaande vervoersmiddelen zou gebruiken om <u>van</u> [P+R Maastricht Noord/P+R Deutersestraat] <u>naar</u> uw eindbestemming te reizen?

Ga ervan uit dat onderstaande vervoersmiddelen <u>wel</u> aanwezig zijn op de P+R.</td><td>Matrix table</td><td>
<table>
<tr><th></th><th>Zeer onwaarschijnlijk</th><th>Onwaarschijnlijk</th><th>Neutraal</th><th>Waarschijnlijk</th><th>Zeer waarschijnlijk</th></tr>
<tr><td>Openbaar vervoer</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elektrische deelfiets (bijv. Bolt, TIER)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelscooter (bijv. Go-Sharing, Felyx, Check</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>PRVervoerMaastricht → Bus OF Trein
PRVervoerDenBosch → Bus</td></tr>
</table>

<table>
<tr><th>ID</th><th>Question</th><th>Answer type</th><th>Answer set</th><th>Routing</th></tr>
<tr><td>AlternatiefEigVOth</td><td>Wanneer [PRVervoerMaastricht/PRVervoerDenBosch] niet beschikbaar is, hoe waarschijnlijk is het dat u een van onderstaande vervoersmiddelen zou gebruiken om <u>van</u> [P+R Maastricht Noord/P+R Deutersestraat] <u>naar</u> uw eindbestemming te reizen?

Ga ervan uit dat onderstaande vervoersmiddelen <u>wel</u> aanwezig zijn op de P+R.</td><td>Matrix table</td><td>
<table>
<tr><th></th><th>Zeer onwaarschijnlijk</th><th>Onwaarschijnlijk</th><th>Neutraal</th><th>Waarschijnlijk</th><th>Zeer waarschijnlijk</th></tr>
<tr><td>Openbaar vervoer</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelfiets (bijv. OV-fiets)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elektrische deelfiets (bijv. Bolt, TIER)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelscooter (bijv. Go-Sharing, Felyx, Check</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>PRVervoerMaastricht → Eigen vervoer OF Anders, namelijk
PRVervoerDenBosch → Eigen vervoer OF Anders, namelijk</td></tr>
</table>

<table>
<tr><th>ID</th><th>Question</th><th>Answer type</th><th>Answer set</th><th>Routing</th></tr>
<tr><td>AlternatiefLopend</td><td>Geef aan hoe waarschijnlijk het is dat u een van onderstaande vervoersmiddelen zou gebruiken om <u>van</u> [P+R Maastricht Noord/P+R Deutersestraat] <u>naar</u> uw eindbestemming te reizen?

Ga ervan uit dat onderstaande vervoersmiddelen aanwezig zijn op de P+R.</td><td>Matrix table</td><td>
<table>
<tr><th></th><th>Zeer onwaarschijnlijk</th><th>Onwaarschijnlijk</th><th>Neutraal</th><th>Waarschijnlijk</th><th>Zeer waarschijnlijk</th></tr>
<tr><td>Openbaar vervoer</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelfiets (bijv. OV-fiets)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elektrische deelfiets (bijv. Bolt, TIER)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Deelscooter (bijv. Go-Sharing, Felyx, Check</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>PRVervoerMaastricht → Lopend
PRVervoerDenBosch → Lopend</td></tr>
<tr><td>OnwOV</td><td>Waarom is het onwaarschijnlijk dat u met het openbaar vervoer <u>van</u> [P+R Maastricht Noord/P+R Deutersestraat] <u>naar</u> uw eindbestemming reist?</td><td>Multiple choice; text</td><td>☐ Ik heb er geen behoefte aan
☐ Ik vind de reis te lang duren
☐ Ik vind het te duur
☐ Ik heb geen abonnement
☐ Ik kom niet bij mijn bestemming met het openbaar vervoer
☐ Ik vind het niet betrouwbaar
☐ Ik vind het niet flexibel</td><td>AlternatiefDeelfiets/ AlternatiefEigVOth/ AlternatiefLopend: Openbaar vervoer → Zeer onwaarschijnlijk OF Onwaarschijnlijk</td></tr>
</table>

ID	Question	Answer type	Answer set	Routing
OnwDeelfiets	Waarom is het onwaarschijnlijk dat u met een deelfiets van [P+R Maastricht Noord/P+R Deutersestraat] naar uw eindbestemming reist?	Multiple choice; text	☐ Ik heb er geen behoefte aan ☐ Ik vind het reizen met een deelfiets te lang duren ☐ Ik vind het te duur ☐ Ik vind het een gedoe om te gebruiken ☐ Ik ben bang dat het niet altijd beschikbaar is als ik het nodig heb ☐ Ik heb het in het verleden geprobeerd en ik was teleurgesteld over de ervaring ☐ Ik vind het te gevaarlijk ☐ Ik heb geen idee hoe ik een deelfiets moet gebruiken	AlternatiefOV/ AlternatiefEigVOth/ AlternatiefLopend: Deelfiets → Zeer onwaarschijnlijk OF Onwaarschijnlijk
OnwElekDeelfiets	Waarom is het onwaarschijnlijk dat u met een elektrische deelfiets van [P+R Maastricht Noord/P+R Deutersestraat] naar uw eindbestemming reist?	Multiple choice; text	☐ Ik heb er geen behoefte aan ☐ Ik vind het reizen met een elektrische deelfiets te lang duren ☐ Ik vind het te duur ☐ Ik vind het een gedoe om te gebruiken ☐ Ik ben bang dat het niet altijd beschikbaar is als ik het nodig heb ☐ Ik heb geen smartphone of andere geschikte telefoon ☐ Ik heb in het verleden een elektrische deelfiets geprobeerd en ik was teleurgesteld over de ervaring ☐ Ik vind het te gevaarlijk ☐ Ik heb geen idee hoe ik een elektrische deelfiets moet gebruiken	AlternatiefOV/ AlternatiefDeelfiets/ AlternatiefEigVOth/ AlternatiefLopend: Deelfiets → Zeer onwaarschijnlijk OF Onwaarschijnlijk

ID	Question	Answer type	Answer set	Routing
OnwDeelscooter	Waarom is het onwaarschijnlijk dat u met een elektrische deelfiets van [P+R Maastricht Noord/P+R Deutersestraat] naar uw eindbestemming reist?	Multiple choice; text	☐ Ik heb er geen behoefte aan ☐ Ik vind het reizen met een deelscooter te lang duren ☐ Ik vind het te duur ☐ Ik vind het een gedoe om te gebruiken ☐ Ik ben bang dat het niet altijd beschikbaar is als ik het nodig heb ☐ Ik heb geen smartphone of andere geschikte telefoon ☐ Ik heb het in het verleden geprobeerd en ik was teleurgesteld over de ervaring ☐ Ik vind het te gevaarlijk ☐ Ik heb geen idee hoe ik een deelscooter moet gebruiken ☐ Ik wil niet reizen met een deelscooter vanwege de helmplicht	AlternatiefOV/ AlternatiefDeelfiets/ AlternatiefEigVOth/ AlternatiefLopend: Deelfiets → Zeer onwaarschijnlijk OF Onwaarschijnlijk

5. Intentions Public Transport and Shared Mobility

ID	Question	Answer type	Answer set	Routing
IntentieAspecten	Geef aan hoe belangrijk u de volgende aspecten vindt in de keuze van vervoermiddel voor uw reis van [P+R Maastricht Noord/P+R Deutersestraat] naar uw eindbestemming.	Matrix table	(see matrix below)	

	Zeer onbelangrijk	Onbelangrijk	Neutraal	Belangrijk	Zeer belangrijk
Reistijd van vervoermiddel					
Meerdere betaalmogelijkheden (bijv. via betaalterminal op locatie, digtaal via app)					
Beschikbaarheid van het vervoermiddel					
Reiskosten					
Eenvoudig in gebruik					
Wacht- en/of overstaptijd op P+R					
Afstand tot de parkeerplaats					
Goede voorzieningen op de P+R (bijv. bushokje, bankjes)					

6. Socio-Demographic Information				
ID	**Question**	**Answer type**	**Answer options**	**Routing**
Geslacht	Wat is uw geslacht?	Select one	○ Vrouw ○ Man ○ Anders ○ Dat zeg ik liever niet	
Leeftijd	Wat is uw leeftijd (in jaren)?	Text (only numbers)	…	
Migratieachtergrond	Waar bent u geboren?	Select one	○ In Nederland ○ In een Europees land ○ In een niet-Europees land ○ Dat zeg ik liever niet	
Opleiding	Wat is de hoogste opleiding die u heeft afgerond?	Select one; text	○ Geen opleiding ○ Basisonderwijs ○ VMBO, VBO, LWOO, VSO, VGLO, MAVO, ULO, MULO ○ HAVO, VWO, MBO-1, MBO-2, MBO-3, MBO-4, MMS, HBS ○ HBO, Universiteit ○ Dat zeg ik liever niet ○ Anders, namelijk: …	
Werksituatie	Wat is uw belangrijkste huidige werksituatie?	Select one; text	○ Werkend (12 tot 30 uur per week) ○ Werkend (30 uur per week of meer) ○ Zelfstandig ondernemer (full-/part time) ○ Huisvrouw, huisman of andere onbetaalde activiteit (vrijwilligers) ○ Scholier/student ○ Met pensioen ○ Werkloos/werkzoekend/bijstand ○ Arbeidsongeschikt ○ Dat zeg ik liever niet ○ Anders, namelijk: …	

7. Digitale mobility skills				
ID	**Question**	**Answer type**	**Answer set**	**Routing**
TelefoonFuncties	Voor welke van de volgende activiteiten heeft u uw smartphone het afgelopen jaar gebruikt? U kunt meerdere antwoorden geven.	Multiple choice	☐ Om te bellen en/of berichten te sturen ☐ Het plannen voor reizen met een eigen vervoermiddel, zoals met Google Maps ☐ Het plannen voor reizen met het openbaar vervoer, zoals met de 9292-app ☐ Het kopen van kaartjes voor het openbaar vervoer, zoals met de NS-app ☐ Het reserveren of boeken van deelvervoer in een app, zoals een deelfiets of deelscooter ☐ Het overmaken van geld naar iemand ☐ Om online iets te kopen ☐ Alle bovenstaande antwoorden ☐ Geen van bovenstaande antwoorden ☐ Dat zeg ik liever niet	

C Survey: Representative population sample ODiN

To check the representativeness of the survey sample, data of the Onderweg in Nederland (ODiN) survey of the CBS (2020, 2023b) were used. For this study, the data is filtered on respondents that make multimodal trips (car + public transport) and live in an area with the same urbanity class as Maastricht and 's-Hertogenbosch. Therefore, the following variables of the data were used to filter the respondents of the ODiN-data:

- **Sted:** variable that indicates the urbanity class ("stedelijkheidsklasse") of the residential municipality of the respondent. The municipality of Maastricht is classified as very strongly urban ("1: zeer sterk stedelijk") and the municipality of Den Bosch as strongly urban ("2: sterk stedelijk") (CBS, 2023a).
- **AantVpl:** variable that indicates the number of trips made by the respondent. As there are respondents included in the data that did not make a trip in the period of surveying, this variable is used to filter out the respondents without any trips.
- **Verpl:** variable that indicates if the data of the selected row is a new trip or not a new trip, so indicating a trip with multiple rides ("ritten"). This variable is used to select multimodal trips as these consist of multiple rides.
- **AantRit:** variable that indicates the number of rides made by the respondents within a specific trip. This variable is used to filter on respondents that make a trip with at least 2 rides.
- **RitNr:** variable that indicates the ride number ("ritnummer") of the trip made by the respondent.
- **Rvm/KRvm:** variable that indicates the type of transportation mode used for the ride.

The survey sample of this research uses a car as first transportation mode and public transport or shared mobility as second transportation mode in the trip from home to destination. Therefore, only respondents using a car as first transportation mode in their trip are included in the representative population sample. This condition is set using the variables Verpl, RitNr and Rvm. From this sample, only respondents that use public transportation as second transportation mode should be included. Again, the data is filtered using Verpl, RitNR and Rvm to get the correct sample. This results in the representative population sample that is used to compare the socio-demographic data of the survey sample. It is also checked if respondents of the ODiN-data first walk or cycle before they use the car and public transportation, but no respondents were found in the data. Besides, no respondents were found that use first public transport and secondly the car to go to their destination.

D Data Analysis: Bikeability index

The bikeability index is a built-environment characteristic included in the regression analysis of this research to analyse the relation between bicycle infrastructure quality and the intention to use shared mobility. The index is calculated for each respondent in the regression analysis sample and the method is based on previous research of Hartanto (2017). To calculate the bikeability index, a shapefile of a bicycle network containing attributes that describe the quality of the infrastructure is required. A dataset of the Fietsersbond (2022) is therefore used for the calculation of the index, as well as the GIS-software ArcGIS Pro.

The first step is the cleaning of the bicycle network. It was found that the network contains roads that are not accessible for cyclists (e.g. highways), and these were removed from the dataset. After cleaning the dataset, an average cycling speed of 13 km/h (Dozza & Werneke, 2014) is added as an attribute, to calculate the travel time per link which is also stored as an attribute. With these attributes, a network dataset could be created which is used to determine the shortest route to each of the indicated destinations using the network analyst in ArcGIS Pro (Esri, 2024b).

To match the links with all bicycle infrastructure characteristics and the generated routes, a spatial join is done that joins the attributes from the target feature (Fietsersbond bicycle network) with the joined feature (shortest bicycle routes to destinations) (Esri, 2024c). The attribute table now contains all the routes to the destinations and bicycle infrastructure attributes sorted per route. This attribute table is exported to Excel for further processing in Python.

The data from the Fietsersbond contains multiple attributes relating to the quality of bicycle infrastructure. Four attributes are chosen to consider in the bikeability index: road type, road surface, road quality and road lighting. The final bikeability index is a combination of four factors calculated first for each attribute separately. This is done for each attribute in the same way. Each category of the attribute is given a variable level based on the service level. The highest value is 1 which indicates that the category is the ideal condition for cycling. The lowest value is 0, which means that the category is far from the ideal condition for cycling.

Each road link in the dataset has a certain category for each attribute, and based on how it contributes to ideal conditions for cycling a value is assigned as mentioned above. Table 18 shows the different variable levels that are linked to each category. For example, for the road type a solitary bike path gets value 1 since that is assumed as the most safest and quickest bicycle infrastructure condition to cycle on. A pedestrianized road or area gets a value of 0.1 as this is a far from ideal bicycle infrastructure condition.

Given the variable levels and the length of each link *i* in the route, the index per bicycle infrastructure attribute is calculated with the following equation:

$$\text{Attribute index} = \frac{\sum \text{link length}_i \times \text{variable level link}_i}{\text{Total route length}} \tag{1}$$

The calculated attribute indices are normalized and the final bikeability index per respondent is calculated with the following equation:

$$\begin{aligned} \text{Bikeability index} = & (\text{Road type index} \times 0.25) + (\text{Road surface index} \times 0.25) \\ & + (\text{Road quality index} \times 0.25) + (\text{Road lighting index} \times 0.25) \end{aligned} \tag{2}$$

Table 18: Variable levels for different bicycle infrastructure attributes

Bicycle infrastructure category	**Level**
Road type	
Solitary bike path	1
Bicycle path along road	0.8
Bicycle street	0.6
Road with suggested bicycle lane	0.4
Normal road or service road	0.2
Pedestrianized road/area	0.1
Road surface	
Asphalt/concrete	1
Bricks or tiles	0.75
Other (e.g. cobblestones) or semi-paved	0.5
Unpaved	0.25
Road quality	
Good	1
Reasonable	0.67
Bad	0.33
Road lighting	
Good lighting	1
Limited lighting	0.67
No lighting	0.33

E Accessibility Analysis: POI Categories

Table 19 shows the POI categories that are considered in the accessibility analysis of this research. The codes of the POI refer to the manual for OpenStreetMap data from Geofabrik (2022).

Table 19: POI categories considered for accessibility analysis

POI-category	Code
Education	208x
Health	21xx
Leisure	22xx
Catering	23xx
Shopping	25xx
Tourism	272x, 273x
Public facilities	200x, 201x

F Data Analysis: Regression analysis parameter estimates

Table 20: Parameter estimates of the ordinal logistic regression model of the intention to use a shared bike

	b	Std. error	Wald	Sig.	Exp(B)	95% confidence interval Lower	Upper
Threshold							
Intention to use shared bike = unlikely	1.778	1.193	2.222	0.136	5.917	-0.560	4.116
Intention to use shared bike = neutral	2.376	1.194	3.958	0.047*	10.760	0.035	4.716
Locations							
Gender = Male	0.163	0.194	0.710	0.400	1.177	-0.217	0.543
Gender = Female	0[a]				1		
Age	0.009	0.008	1.306	0.253	1.009	-0.007	0.025
Education level = Low	0.091	0.324	0.079	0.779	1.095	-0.543	0.725
Education level = Medium	-0.234	0.209	1.251	0.263	0.792	-0.643	0.176
Education level = High	0[a]				1		
Occupation status = Employed (12 to 30 hours per week)	0.168	0.336	0.251	0.617	1.183	-0.490	0.827
Occupation status = Employed (30 hours per week or more)	0.045	0.328	0.019	0.891	1.046	-0.598	0.688
Occupation status = Self-employed (full/parttime)	0.239	0.433	0.304	0.581	1.270	-0.610	1.087
Occupation status = Working in household or other unpaid activity	0.121	0.661	0.034	0.854	1.129	-1.175	1.148
Occupation status = Student	-0.756	0.681	1.231	0.267	0.470	-2.092	0.580
Occupation status = Unemployed/Unable to work	-0.956	1.327	0.518	0.472	0.385	-3.557	1.646
Occupation status = In retirement	0[a]				1		
Migration background = Dutch background	0.416	0.475	0.766	0.381	1.516	-0.515	1.347
Migration background = Non-Dutch background	0[a]				1		
Walking difficulty = No	0.898	0.327	7.567	0.006*	2.456	0.258	1.539
Walking difficulty = Yes	0[a]				1		
Shared mobility experience = No	-1.942	0.233	69.234	<0.001*	0.143	-2.400	-1.485
Shared mobility experience = Yes	0[a]				1		
Frequency of public transport usage = Never	-0.425	0.576	0.544	0.461	0.654	-1.554	0.705
Frequency of public transport usage = 1-5 days per year	-0.191	0.445	0.184	0.668	0.826	-1.064	0.682
Frequency of public transport usage = 6-11 days per year	0.012	0.462	0.001	0.980	1.012	-0.893	0.916
Frequency of public transport usage = 1-3 days per month	-0.396	0.491	0.651	0.420	0.673	-1.357	0.566
Frequency of public transport usage = 1-3 days per week	-0.645	0.459	1.974	0.160	0.525	-1.545	0.255
Frequency of public transport usage = 4 or more days per week	0[a]				1		
Frequency of P+R usage = This is the first time	1.109	0.598	3.442	0.064	3.033	-0.063	2.282
Frequency of P+R usage = 1-5 days per year	0.980	0.568	2.980	0.084	2.664	-0.133	2.092
Frequency of P+R usage = 6-11 days per year	0.516	0.594	0.754	0.385	1.676	-0.649	1.681
Frequency of P+R usage = 1-3 days per month	0.364	0.637	0.326	0.568	1.439	-0.885	1.613
Frequency of P+R usage = 1-3 days per week	0.704	0.532	1.749	0.186	2.021	-0.339	1.747
Frequency of P+R usage = 4 or more days per week	0[a]				1		
Trip purpose = To and from work	1.094	0.621	3.103	0.078	2.986	-0.123	2.311
Trip purpose = Shopping	-0.127	0.473	0.072	0.789	0.881	-1.054	0.801
Trip purpose = Services/care	1.467	1.117	1.725	0.189	4.337	-0.722	3.656
Trip purpose = Education, training, childcare	0.770	0.760	1.027	0.311	2.160	-0.720	2.260
Trip purpose = Visit family or friends	0.127	0.698	0.033	0.856	1.135	-1.241	1.495
Trip purpose = Sport, hobby, hospitality	-0.078	0.540	0.021	0.886	0.925	-1.136	0.980
Trip purpose = Touring/hiking	0[a]				1		
Travel company = I travelled alone	0.208	0.367	0.321	0.571	1.231	-0.511	0.927
Travel company = I travelled with one other person	0.407	0.269	2.284	0.131	1.502	-0.121	0.935
Travel company = I travelled with two or more other persons	0[a]				1		
Digital skills level = Level 0/1	0.054	0.310	0.031	0.861	1.056	-0.553	0.662
Digital skills level = Level 2	0.307	0.459	0.448	0.503	1.360	-0.593	1.207
Digital skills level = Level 3A	0.138	0.194	0.508	0.476	1.149	-0.242	0.519
Digital skills level = Level 3B	0[a]				1		
Travel time = Unimportant	-0.182	0.462	0.155	0.694	0.834	-1.088	0.724
Travel time = Neutral	-0.063	0.257	0.059	0.808	0.939	-0.566	0.441
Travel time = Important	0[a]				1		
Travel costs = Unimportant	-0.238	0.552	0.185	0.667	0.788	-1.321	0.845
Travel costs = Neutral	0.113	0.259	0.189	0.664	1.119	-0.395	0.620
Travel costs = Important	0[a]				1		
Payment methods at P+R = Unimportant	-0.245	0.306	0.639	0.424	0.783	-0.845	0.356
Payment methods at P+R = Neutral	-0.281	0.195	2.069	0.150	0.755	-0.664	0.102
Payment methods at P+R = Important	0[a]				1		

	b	Std. error	Wald	Sig.	Exp(B)	95% confidence interval Lower	Upper
Availability of transport mode = Unimportant	-0.350	0.723	0.235	0.628	0.704	-1.768	1.067
Availability of transport mode = Neutral	-0.899	0.437	4.242	0.039*	0.407	-1.755	-0.044
Availability of transport mode = Important	0[a]				1		
Ease of use transport mode = Unimportant	0.964	0.946	1.038	0.308	2.622	-0.891	2.819
Ease of use transport mode = Neutral	-0.025	0.399	0.004	0.950	0.975	-0.807	0.758
Ease of use transport mode = Important	0[a]				1		
Waiting time at P+R = Unimportant	-0.480	0.838	0.329	0.567	0.619	-2.123	1.162
Waiting time at P+R = Neutral	0.154	0.292	0.279	0.597	1.167	-0.419	0.727
Waiting time at P+R = Important	0[a]				1		
Distance to parking place = Unimportant	0.146	0.503	0.084	0.772	1.157	-0.840	1.133
Distance to parking place = Neutral	-0.121	0.248	0.238	0.626	0.886	-0.607	0.365
Distance to parking place = Important	0[a]				1		
Facilities at P+R location = Unimportant	0.062	0.301	0.042	0.837	1.064	-0.528	0.652
Facilities at P+R location = Neutral	-0.198	0.196	1.024	0.312	0.820	-0.583	0.186
Facilities at P+R location = Important	0[a]				1		
Bikeability index	0.286	1.008	0.080	0.777	1.331	-1.691	2.262
Distance to destination	0.001	0.005	0.050	0.823	1.001	-0.010	0.012

Link function: Logit
[a] This parameter is set to zero because it is redundant.
* Significant at the 0.05 statistical level (95% confidence level)

Table 21: Parameter estimates of the ordinal logistic regression model of the intention to use a shared e-bike

	b	Std. error	Wald	Sig.	Exp(B)	95% confidence interval Lower	Upper
Threshold							
Intention to use shared e-bike = unlikely	-0.519	1.166	0.198	0.656	0.595	-2.804	1.766
Intention to use shared e-bike = neutral	0.179	1.166	0.024	0.878	1.196	-2.105	2.464
Locations							
Gender = Male	0.180	0.197	0.836	0.361	1.197	-0.206	0.565
Gender = Female	0[a]				1		
Age	-0.004	0.008	0.210	0.646	0.996	-0.019	0.012
Education level = Low	0.085	0.320	0.070	0.791	1.088	-0.543	0.712
Education level = Medium	0.116	0.204	0.324	0.569	1.123	-0.284	0.517
Education level = High	0[a]				1		
Occupation status = Employed (12 to 30 hours per week)	-0.072	0.330	0.047	0.828	0.931	-0.719	0.575
Occupation status = Employed (30 hours per week or more)	-0.404	0.327	1.522	0.217	0.668	-1.046	0.238
Occupation status = Self-employed (full/parttime)	-0.395	0.430	0.840	0.359	0.674	-1.238	0.449
Occupation status = Working in household or other unpaid activity	0.432	0.612	0.498	0.480	1.540	-0.767	1.631
Occupation status = Student	-0.956	0.700	1.866	0.172	0.384	-2.328	0.416
Occupation status = Unemployed/Unable to work	-19.588	0.000			0.000	-19.588	-19.588
Occupation status = In retirement	0[a]				1		
Migration background = Dutch background	-1.034	0.419	6.093	0.014*	0.356	-1.855	-0.213
Migration background = Non-Dutch background	0[a]				1		
Walking difficulty = No	0.502	0.321	2.448	0.118	1.652	-0.127	1.130
Walking difficulty = Yes	0[a]				1		
Shared mobility experience = No	-0.763	0.224	11.572	0.001*	0.466	-1.203	-0.324
Shared mobility experience = Yes	0[a]				1		
Frequency of public transport usage = Never	-0.358	0.598	0.358	0.550	0.699	-1.531	0.815
Frequency of public transport usage = 1-5 days per year	0.134	0.456	0.087	0.768	1.144	-0.760	1.028
Frequency of public transport usage = 6-11 days per year	0.419	0.472	0.788	0.375	1.521	-0.506	1.345
Frequency of public transport usage = 1-3 days per month	-0.321	0.510	0.397	0.528	0.725	-1.320	0.677
Frequency of public transport usage = 1-3 days per week	-0.268	0.474	0.320	0.572	0.765	-1.198	0.662
Frequency of public transport usage = 4 or more days per week	0[a]				1		
Frequency of P+R usage = This is the first time	0.649	0.611	1.125	0.289	1.913	-0.550	1.847
Frequency of P+R usage = 1-5 days per year	0.343	0.581	0.347	0.556	1.409	-0.797	1.482
Frequency of P+R usage = 6-11 days per year	0.125	0.611	0.042	0.838	1.133	-1.072	1.322
Frequency of P+R usage = 1-3 days per month	0.228	0.665	0.118	0.731	1.257	-1.075	1.531
Frequency of P+R usage = 1-3 days per week	0.423	0.549	0.594	0.441	1.526	-0.652	1.498
Frequency of P+R usage = 4 or more days per week	0[a]				1		
Trip purpose = To and from work	0.607	0.621	0.954	0.329	1.834	-0.611	1.824
Trip purpose = Shopping	0.044	0.481	0.008	0.928	1.045	-0.900	0.987
Trip purpose = Services/care	1.820	1.098	2.747	0.097	6.172	-0.332	3.972
Trip purpose = Education, training, childcare	0.218	0.807	0.073	0.787	1.244	-1.363	1.799
Trip purpose = Visit family or friends	0.985	0.676	2.123	0.145	2.677	-0.340	2.309
Trip purpose = Sport, hobby, hospitality	-0.169	0.553	0.094	0.760	0.844	-1.252	0.914
Trip purpose = Touring/hiking	0[a]				1		
Travel company = I travelled alone	0.042	0.361	0.014	0.907	1.043	-0.665	0.750
Travel company = I travelled with one other person	0.280	0.265	1.114	0.291	1.323	-0.240	0.799
Travel company = I travelled with two or more other persons	0[a]				1		
Digital skills level = Level 0/1	-0.291	0.313	0.863	0.353	0.747	-0.905	0.323
Digital skills level = Level 2	-0.602	0.538	1.253	0.263	0.548	-1.657	0.452
Digital skills level = Level 3A	-0.133	0.194	0.472	0.492	0.875	-0.514	0.247
Digital skills level = Level 3B	0[a]				1		
Travel time = Unimportant	-0.442	0.494	0.800	0.371	0.643	-1.411	0.527
Travel time = Neutral	-0.170	0.256	0.439	0.508	0.844	-0.672	0.333
Travel time = Important	0[a]				1		
Travel costs = Unimportant	0.004	0.552	0.000	0.995	1.004	-1.079	1.086
Travel costs = Neutral	-0.427	0.278	2.363	0.124	0.652	-0.972	0.117
Travel costs = Important	0[a]				1		
Payment methods at P+R = Unimportant	-0.875	0.338	6.705	0.010*	0.417	-1.537	-0.213
Payment methods at P+R = Neutral	-0.429	0.197	4.724	0.030*	0.651	-0.816	-0.042
Payment methods at P+R = Important	0[a]				1		
Availability of transport mode = Unimportant	0.520	0.700	0.553	0.457	1.683	-0.851	1.891
Availability of transport mode = Neutral	-0.049	0.399	0.015	0.903	0.953	-0.830	0.733
Availability of transport mode = Important	0[a]				1		
Ease of use transport mode = Unimportant	0.516	0.849	0.370	0.543	1.676	-1.147	2.180
Ease of use transport mode = Neutral	0.120	0.403	0.089	0.765	1.128	-0.669	0.909
Ease of use transport mode = Important	0[a]				1		

	b	Std. error	Wald	Sig.	Exp(B)	95% confidence interval Lower	Upper
Waiting time at P+R = Unimportant	-0.318	0.845	0.142	0.706	0.727	-1.974	1.337
Waiting time at P+R = Neutral	0.079	0.292	0.072	0.788	1.082	-0.494	0.652
Waiting time at P+R = Important	0[a]				1		
Distance to parking place = Unimportant	-0.002	0.516	0.000	0.997	0.998	-1.013	1.009
Distance to parking place = Neutral	0.059	0.247	0.056	0.813	1.060	-0.426	0.543
Distance to parking place = Important	0[a]				1		
Facilities at P+R location = Unimportant	0.439	0.290	2.281	0.131	1.551	-0.131	1.008
Facilities at P+R location = Neutral	-0.340	0.201	2.855	0.091	0.712	-0.734	0.054
Facilities at P+R location = Important	0[a]				1		
Bikeability index	-0.192	0.980	0.038	0.845	0.825	-2.112	1.729
Distance to destination	0.005	0.005	0.987	0.321	1.005	-0.005	0.015

Link function: Logit

[a] This parameter is set to zero because it is redundant.

* Significant at the 0.05 statistical level (95% confidence level)

Table 22: Parameter estimates of the ordinal logistic regression model of the intention to use a shared e-moped

	b	Std. error	Wald	Sig.	Exp(B)	95% confidence interval Lower	Upper
Threshold							
Intention to use shared e-moped = unlikely	-2.288	1.481	2.388	0.122	0.101	-5.191	0.614
Intention to use shared e-moped = neutral	-1.077	1.479	0.530	0.466	0.341	-3.976	1.822
Locations							
Gender = Male	0.227	0.249	0.829	0.363	1.255	-0.262	0.716
Gender = Female	0[a]				1		
Age	-0.035	0.010	12.698	<0.001*	0.965	-0.054	-0.016
Education level = Low	0.491	0.391	1.581	0.209	1.634	-0.275	1.257
Education level = Medium	0.417	0.257	2.636	0.104	1.517	-0.086	0.919
Education level = High	0[a]				1		
Occupation status = Employed (12 to 30 hours per week)	0.106	0.504	0.044	0.834	1.111	-0.882	1.093
Occupation status = Employed (30 hours per week or more)	0.100	0.493	0.041	0.839	1.105	-0.866	1.066
Occupation status = Self-employed (full/parttime)	-0.019	0.595	0.001	0.974	0.981	-1.185	1.147
Occupation status = Working in household or other unpaid activity	1.031	0.808	1.629	0.202	2.803	-0.552	2.613
Occupation status = Student	-0.419	0.814	0.265	0.607	0.658	-2.014	1.176
Occupation status = Unemployed/Unable to work	-17.525	0.000			0.000	-17.525	-17.525
Occupation status = In retirement	0[a]				1		
Migration background = Dutch background	-0.582	0.509	1.304	0.253	0.559	-1.580	0.416
Migration background = Non-Dutch background	0[a]				1		
Walking difficulty = No	-0.524	0.351	2.237	0.135	0.592	-1.212	0.163
Walking difficulty = Yes	0[a]				1		
Ability to use e-moped = No	-19.392	7229.225	0.000	0.998	0.000	-14188.412	14149.628
Ability to use e-moped = I do not know/Never tried	-1.155	0.441	6.855	0.009*	0.315	-2.019	-0.290
Ability to use e-moped = Yes	0[a]				1		
Shared mobility experience = No	-0.625	0.264	5.610	0.018*	0.535	-1.142	-0.108
Shared mobility experience = Yes	0[a]				1		
Frequency of public transport usage = Never	0.153	0.655	0.055	0.815	1.165	-1.130	1.436
Frequency of public transport usage = 1-5 days per year	-0.118	0.538	0.048	0.826	0.888	-1.173	0.936
Frequency of public transport usage = 6-11 days per year	-0.528	0.562	0.883	0.347	0.590	-1.629	0.573
Frequency of public transport usage = 1-3 days per month	-0.356	0.581	0.376	0.540	0.700	-1.495	0.783
Frequency of public transport usage = 1-3 days per week	-0.141	0.545	0.067	0.795	0.868	-1.210	0.927
Frequency of public transport usage = 4 or more days per week	0[a]				1		
Frequency of P+R usage = This is the first time	-0.202	0.716	0.079	0.778	0.817	-1.604	1.201
Frequency of P+R usage = 1-5 days per year	-0.716	0.695	1.061	0.303	0.489	-2.078	0.646
Frequency of P+R usage = 6-11 days per year	-0.741	0.736	1.014	0.314	0.477	-2.183	0.701
Frequency of P+R usage = 1-3 days per month	-0.469	0.813	0.333	0.564	0.625	-2.063	1.124
Frequency of P+R usage = 1-3 days per week	-0.082	0.622	0.017	0.896	0.922	-1.301	1.138
Frequency of P+R usage = 4 or more days per week	0[a]				1		
Trip purpose = To and from work	-0.434	0.840	0.267	0.605	0.648	-2.079	1.212
Trip purpose = Shopping	0.090	0.649	0.019	0.890	1.094	-1.182	1.362
Trip purpose = Services/care	0.877	1.413	0.386	0.535	2.405	-1.892	3.646
Trip purpose = Education, training, childcare	-1.739	1.265	1.890	0.169	0.176	-4.219	0.740
Trip purpose = Visit family or friends	0.684	0.854	0.642	0.423	1.982	-0.989	2.357
Trip purpose = Sport, hobby, hospitality	-0.024	0.747	0.001	0.974	0.976	-1.489	1.441
Trip purpose = Touring/hiking	0[a]				1		
Travel company = I travelled alone	0.266	0.445	0.358	0.550	1.305	-0.606	1.139
Travel company = I travelled with one other person	0.214	0.330	0.419	0.517	1.238	-0.434	0.861
Travel company = I travelled with two or more other persons	0[a]				1		
Digital skills level = Level 0/1	-0.232	0.412	0.317	0.573	0.793	-1.040	0.576
Digital skills level = Level 2	-1.806	1.097	2.708	0.100	0.164	-3.957	0.345
Digital skills level = Level 3A	-0.077	0.243	0.101	0.750	0.926	-0.554	0.399
Digital skills level = Level 3B	0[a]				1		
Travel time = Unimportant	-0.153	0.589	0.067	0.795	0.859	-1.306	1.001
Travel time = Neutral	-0.322	0.358	0.807	0.369	0.725	-1.024	0.380
Travel time = Important	0[a]				1		
Travel costs = Unimportant	0.230	0.696	0.109	0.741	1.258	-1.134	1.593
Travel costs = Neutral	0.021	0.340	0.004	0.952	1.021	-0.646	0.687
Travel costs = Important	0[a]				1		
Payment methods at P+R = Unimportant	-0.283	0.390	0.526	0.468	0.754	-1.046	0.481
Payment methods at P+R = Neutral	-0.167	0.247	0.461	0.497	0.846	-0.651	0.316
Payment methods at P+R = Important	0[a]				1		
Availability of transport mode = Unimportant	1.804	0.781	5.337	0.021*	6.072	0.273	3.334
Availability of transport mode = Neutral	-0.392	0.574	0.467	0.494	0.676	-1.517	0.732
Availability of transport mode = Important	0[a]				1		

	b	Std. error	Wald	Sig.	Exp(B)	95% confidence interval Lower	Upper
Ease of use transport mode = Unimportant	0.065	0.978	0.004	0.947	1.068	-1.851	1.982
Ease of use transport mode = Neutral	0.102	0.495	0.043	0.836	1.108	-0.868	1.072
Ease of use transport mode = Important	0[a]				1		
Waiting time at P+R = Unimportant	-0.654	1.146	0.326	0.568	0.520	-2.900	1.592
Waiting time at P+R = Neutral	0.297	0.363	0.671	0.413	1.346	-0.414	1.009
Waiting time at P+R = Important	0[a]				1		
Distance to parking place = Unimportant	-0.152	0.643	0.056	0.813	0.859	-1.411	1.107
Distance to parking place = Neutral	-0.359	0.325	1.217	0.270	0.699	-0.996	0.278
Distance to parking place = Important	0[a]				1		
Facilities at P+R location = Unimportant	-0.075	0.361	0.043	0.835	0.928	-0.783	0.633
Facilities at P+R location = Neutral	-0.504	0.253	3.983	0.046	0.604	-0.999	-0.009
Facilities at P+R location = Important	0[a]				1		
Bikeability index	0.050	1.318	0.001	0.970	1.051	-2.533	2.633
Distance to destination	0.008	0.006	1.784	0.182	1.008	-0.004	0.020

Link function: Logit

[a] This parameter is set to zero because it is redundant.

* Significant at the 0.05 statistical level (95% confidence level)