The Future of Community Mobility Hubs in M4H

ADDRESSING DIVERSE USER NEEDS THROUGH VIRTUAL REALITY-ASSISTED STUDIES

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Abstract

This research explores user feedback on proposed mobility solutions in the Merwe-Vierhavens (M4H) area of Rotterdam to inform the development of Community Mobility Hubs (CMHs). Conducted in two phases, the study began with socio-demographic analysis, followed by Virtual Reality (VR) simulations. The initial phase involved desk research to understand the demographic composition and travel patterns in neighborhoods around M4H. Findings revealed a diverse community with a young population (27-39 years old), including European, Turkish, Moroccan migrants, and Dutch non-migrants, primarily in low-income single or family-with-children households. Mobility patterns showed varied travel purposes, such as shopping, commuting, and recreational activities, with walking, cycling, passenger cars, and public transport being the most common modes of transportation.

The second phase used VR to provide an immersive experience of the proposed CMH, engaging participants and gathering detailed feedback. Key findings indicated a strong preference for amenities like cafes, co-working spaces, postal services, and refurbishing centers, especially among first- and second-generation migrants. Significant concerns about affordability, reliability, and availability of mobility solutions were also highlighted.

Despite limitations such as potential biases in self-reported data and the fixed nature of the VR simulation, the study's innovative use of VR provided valuable insights. Recommendations for the CMH include creating solutions for diverse demographics, focusing on families, people of migrant backgrounds, and low-income groups, ensuring accessible, affordable, acceptable, and available transport options. The CMH should incorporate practical features to accommodate various activities, address concerns about affordability, availability, and reliability through ongoing community dialogue, and emphasize convenience, good maintenance, and diverse pricing schemes. Affordable transportation solutions should be offered, targeting user groups most likely to adopt the solutions, such as females and people of migrant backgrounds. Comprehensive services and family-friendly amenities should be included, and community ownership and management encouraged. Both digital and non-digital access points should be provided, and continuous community engagement maintained.

Future research should expand the sample size for better representation and include longitudinal studies to track evolving mobility preferences. Enhancing VR simulation quality and addressing potential biases from tech-savvy participants will provide more balanced insights. This research underscores the importance of understanding diverse mobility needs and innovative citizen participation utilizing VR to create inclusive and effective urban mobility solutions for the M4H community.

Key Words

Community Mobility Hub, Virtual Reality, Citizen Participation, Socio-Demographic Analysis, M4H, Rotterdam, User-Centered Mobility Solutions, Shared Mobility

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Glossary

M4H	Merwe-Vierhavens is an area in Rotterdam that is undergoing urban development.
CMH	Community Mobility Hub is a centralized location that integrates various modes of transportation and services.
VR	Virtual Reality is a technology that simulates a realistic environment for users to interact with.
Shared Mobility	Transportation services shared among users, providing an alternative to private car ownership.
Focus Group	A small, diverse group of people whose reactions are studied in guided discussions.
Immersive Experience	A simulation that fully engages the user's senses, creating a realistic and engaging environment.
Community Ownership	The involvement and responsibility of local community members in managing and maintaining shared resources or facilities.
Urban Development	The process of developing land and infrastructure in urban areas.
Citizen Participation	The involvement of citizens in the decision-making processes of urban planning and development ensures their needs and preferences are considered.

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1.Introduction

1.1 Context

Cities worldwide are at a critical point. Rapid urbanization and climate change create more and more challenges related to maintaining healthy ecosystems in urban settings. As metropolitan populations grow, there is a need for sustainable and efficient mobility solutions. Car-centric models of transportation were proven to be no longer suited to modern demand. Not only are they harmful to our planet, but also can be detrimental to our health. It is said that 61% of total CO2 emissions from road transport in Europe are caused by passenger cars (European Parliament, 2023). In addition, over the past decades, public spaces have been designed with a car-centric approach leaving much less space for pedestrians or users of active modes of transport. Moreover, approximately 1.19 million people die annually because of traffic accidents (WHO, 2023). It has also been researched that people driving cars regularly are much less physically active (Ding et al., 2014). Furthermore, the polluted air has negative effects on human health and well-being (European Environment Agency, 2023). There is a need for innovative approaches that prioritize an efficient use of public space, are less harmful to the environment and better for human health.

1.1.1 Emergence of New Mobility Strategies

To tackle climate and health issues caused by, i.e., poor systems no longer suited to the modern lifestyle and demand, cities are changing their approach to design and planning. Streets are increasingly redesigned for shared vehicles, micromobility, and for people and not cars (EU Urban Mobility Observatory, 2020). There is a general mobility transition notion.

The goal is to shift away from private vehicle use, prioritize active mobility, and make commuting more sustainable. For example, in recent years, many cities worldwide have seen a surge in the use of shared mobility. Various systems have been developed where users can access different modes of transportation on-demand for a limited time. This approach aims to reduce private vehicle ownership while providing similar opportunities.

Those opportunities are often offered at mobility hubs. The concept of mobility hubs aims to provide shared mobility options in one location. They are places where users can easily borrow an available vehicle (e.g., a moped, a bike, or a car), most often by using a mobile app. This way, an easy switch between different modes can take place (Posad Maxwan, n.d.).

Additionally, new city developments are planned to give more opportunities for various activities within a short reach to activate neighborhoods and build communities. So-called ‘mixed-use designs’ combine not only living and working, but also shopping, healthcare, education, or leisure (Gattupalli, 2023).

Those innovative approaches shape cities in a new way, aiming to create more sustainable neighborhoods reliant on local opportunities and build stronger communities.

1.1.2 The Usage of Virtual Reality in Urban Planning

While cities are changing and planning innovative solutions for the future, many studies aim to help understand possible future scenarios and realize their implications better so that optimal choices can be made. For

example, the use of Virtual Reality (VR) in urban planning has been growing in recent years.

VR can be used as a method to visualize and conceptualize possible future scenarios and help to understand them better by letting people immerse themselves in virtual realities and experience what a future could look like. For example, VR can be used to assess the interaction between automated vehicles and humans (Feng et al., 2023). Such studies create unique opportunities to evaluate, gather feedback, and understand potential human behaviors better. In addition, while it has not yet been widely applied, VR can create unique opportunities for engaging citizens in the planning process to make better-informed decisions about future neighborhood plans.

Applying VR to study possible future mobility strategies with citizens can aid the mobility transition and make the process more inclusive. VR can facilitate participatory planning by allowing various user groups (e.g., citizens) to experience different scenarios and provide feedback, thereby ensuring that urban designs and new mobility strategies are more user-centered (Azofeifa et al., 2022).

1.2 Project Background

1.2.1 Merwe-Vierhavens, Rotterdam

An example of a neighborhood where new mobility strategies will be applied is Merwe-Vierhavens (M4H) in Rotterdam. M4H is an industrial site located in the west of the city (Figure 1). It covers approximately two hundred hectares, which makes it comparable in size to the city center of Rotterdam (Rotterdam Makers District et al., 2019).

Figure 1 M4H Location

M4H was constructed as a general cargo port between 1916 and 1930 and was among the last expansions of Rotterdam's ports. However, the area was severely damaged during World War II and got its second life in the 70s and 80s as a fruit port and partially serves this function until today (Drift et al., 2017). In addition to that, the area currently also hosts various entrepreneurs and spaces for innovation and experimentation while maintaining the industrial look (Figure 2 and 3).

Figure 2 View on M4H Marconistraat and Gustoweg in Rotterdam

Figure 3 Offices at Galileistraat in Rotterdam

However, soon the port activities will be moved elsewhere, and the municipality and port authorities want to redevelop the area into a new living and working neighborhood that would create perfect conditions for culture, catering, sports, and education (Delva, 2019).

The new plans aim to transform M4H into an innovative urban district with space for living and working next to experimentation. The main spatial approach will free up room for more green urban spaces and allow more functions on the street level. The goal is to create an inclusive neighborhood with various housing types, including around 25% designated to social housing and 20% to mid-range rental. Alongside that, amenities such as primary schools and medical centers will also be built (Gemeente Rotterdam, 2023).

The mobility strategy in M4H aims to prevent traffic overload and promote sustainable alternatives. It primarily focuses on **reducing on- street parking and promoting cycling, shared mobility options, and public transportation** (Rotterdam Makers District, 2019).

The concept aims to serve various target groups, such as:

- *entrepreneurs/employees in the manufacturing industry who use vans and trucks for goods transport.*
- *entrepreneurs/employees who commute from home to work daily.*
- *residents of M4H who mainly travel within the city.*
- *residents of M4H who travel within the entire Randstad area.*
- *visitors of public functions in M4H.*
- *residents from surrounding neighborhoods who use facilities in M4H.*
- *the existing logistics-related companies in the port (APPM Management Consultants et al., 2022).*

The promotion of alternatives to private car use includes the development of a dense network for cyclists and pedestrians, ensuring that these modes of transport are safe, attractive, and well-integrated with the rest of the city. The emphasis on cycling and walking will be supported by the creation of inviting public spaces and well-lit, socially safe routes, making these active modes of transport the preferred choice for residents and visitors alike (APPM Management Consultants et al., 2022).

In addition to enhancing pedestrian and cycling infrastructure, the mobility

strategy places a strong emphasis on shared mobility solutions. These include bike-sharing and car-sharing programs, which will be facilitated through a Mobility as a Service (MaaS) platform (APPM Management Consultants et al., 2022).

Another key element of the M4H mobility strategy, central to this research, is the establishment of mobility hubs. These hubs will be strategically located to ensure that all functions in the area are within a reasonable walking distance (maximum of 400 meters) from a hub (black circles on Figure 4) (APPM Management Consultants et al., 2022).

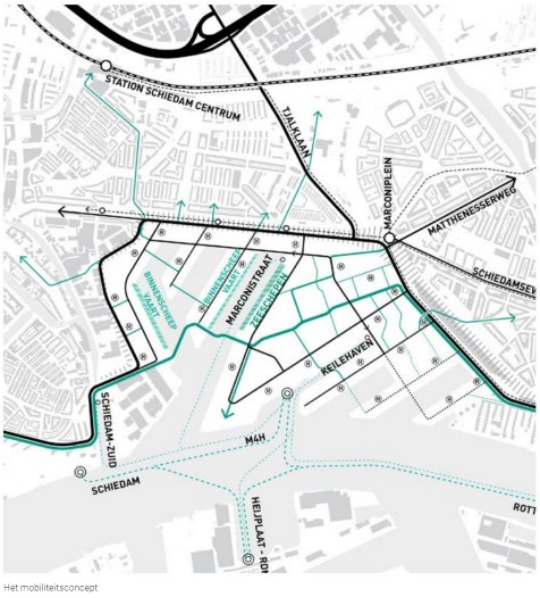

Figure 4 Planned Mobility Hub Locations (Delva, 2019)

The hubs are planned as facilities that will host mobility functions and additional services serving the communities and users from the target groups listed above. In this project, they are described as Community Mobility Hubs (CMH).

A detailed description of the planned developments and the mobility strategy can be found in Appendix A.

1.2.2 Project Stakeholders

The city of Rotterdam, Deloitte, and MINI, a part of the BMW group, are working together to test potential solutions that would contribute to developments such as M4H and help build communities not as reliant on private cars.

Working together on a project called "Urban Community Vehicle" (UCV), they aim to explore what additional functions CMH and the vehicles available in it (UCVs) could have to not only offer sustainable communal mobility options but also aid neighborhoods in other ways. As part of the project, Deloitte has developed a commercial VR model of the CMH to showcase potential additional roles of UCVs and features of such a facility. This model was used for one of the main data collection methods in this research.

Furthermore, this research was conducted as part of an internship at the municipality of Rotterdam, which provided a unique opportunity to connect with the right stakeholders and understand the context of the M4H development first-hand. During the project, Deloitte and MINI were supporting actors by providing additional information and access to the research tools (i.e. the VR model).

Finally, this research was closely associated with two research labs at TU Delft: Mobility in eXtended Reality Lab (MXR) and Seamless Personal Mobility Lab. The MXR lab focuses on conducting research to study interactions among mobility, space, and technologies to tackle the complexity of mobility behavior from the social, temporal, and spatial dynamics (Mobility in eXtended Reality Lab, n.d.). The Seamless Personal Mobility Lab focuses on researching travellers' needs and behaviors

(Seamless Personal Mobility Lab, n.d.).The directors of these labs served as supervisors of this thesis. As a member of these research teams, I was able to leverage their resources and knowledge.

1.3 Research Opportunity, Objectives and Questions

Understanding the socio-demographic backgrounds, and daily patterns of people living in proximity to places (i.e. community context) that are to be redeveloped can help create coherent plans that serve not only the future but also existing communities (Owuondo, 2024). According to Pozoukidou & Angelidou (2022), such an approach could, for example, foster socio-economic cohesion. Moreover, Gagan Deep (2023) claims that including citizens in urban planning processes can promote social fairness and lead to more inclusive developments.

Therefore, it is crucial to recognize who the existing communities around M4H are and how the proposed solutions, such as the new CMH, fit within their current habits and needs. Additionally, involving them in the planning processes can create opportunities for gathering relevant user feedback prior to the project's execution. Utilizing VR for this purpose can also create a unique chance to innovate the citizen participation process.

Combining these approaches can increase inclusivity and adaptation to the new development. To ensure the proposed mobility plan for M4H serves future residents, workers, visitors, and current residents, it is important to involve communities in the planning and decision-making phases. This collaborative approach will result in a livable neighborhood where diverse groups can fully capitalize on urban opportunities (Nazier, 2022).

Therefore, this research aimed to support the M4H development project by (1) helping to understand the community context and (2) allowing potential future users to experience the proposed scenario in Deloitte's VR environment. By providing this immersive experience, participants could reflect on how the features of the CMH can be tailored to suit their needs and habits, thereby informing an inclusive future plan for M4H's mobility hubs.

The research was guided by several objectives:

1. *Provide insights into the demographic and socio-economic profiles of the communities around M4H (also considered potential future users) (O1).*

2. *Provide insights into the primary mobility patterns of communities around M4H (also considered potential future users) (O2).*

3. *Gather user feedback on the current plans for the CMH (O3).*

4. *Develop feature recommendations to meet diverse user needs (O4).*

5. *Investigate the effectiveness of innovative technologies for citizen engagement (O5).*

To reach the research aim and objectives the research was guided by the following research questions listed in Table 1.

Main research question (RQ)	
How can the proposed Community Mobility Hub in M4H be adapted to meet the diverse needs of its potential users?	
Sub-questions	
RQ1.1	What are the demographic and socioeconomic profiles of communities around M4H?
RQ1.2	What are the primary mobility patterns of communities around M4H?
RQ1.3	How do different user groups perceive the current plans for the M4H Community Mobility Hub?
RQ1.4	What additional features or services do users recommend for the Community Mobility Hub?
RQ1.5	How effective are innovative technologies in enhancing citizen engagement in urban planning processes?

Table 1 Research Questions

1.4 Report Structure

The report is divided into several chapters. Chapter 2 explains the theoretical framework used to support this research grounding the approach in existing theories and knowledge. The two following chapters separate this report into Part 1 and Part 2. In Part 1, Chapter 3 focuses on describing the community context. The data collection methods for this part are explained in Chapter 3.1 and results follow in Chapter 3.2. In Part 2, Chapter 4 focuses on the VR experience building upon findings from Chapter 3. Therefore, Chapter 4.1 explains the methods of the VR experience data collection and Chapter 4.2 presents the results. Next, Chapter 5, Discussion, dives into not only the findings but also the limitations of the study. Finally, the report concludes in Chapter 6.

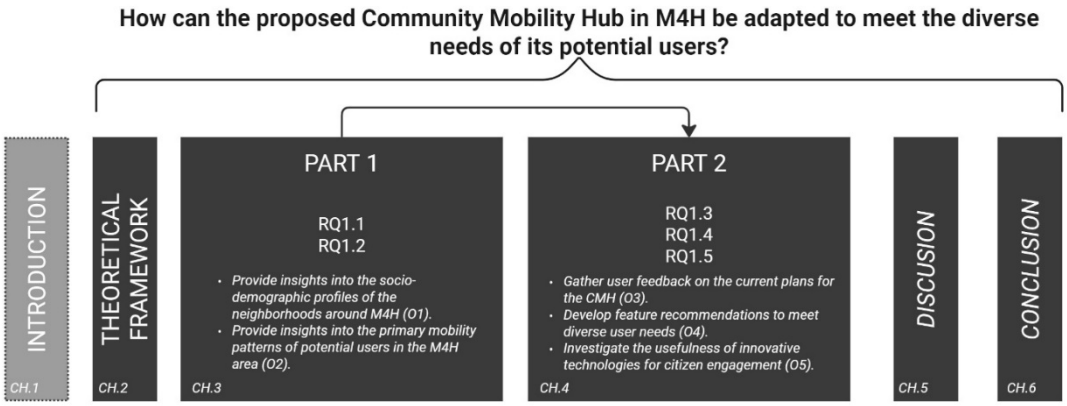

Figure 5 Report Structure

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2. Theoretical Framework

The theoretical framework provides the foundation for this research by linking this study to existing knowledge. As this research is grounded in the field of mobility and particularly future mobility solutions, it is important to review knowledge about contemporary trends, societal aspects of change, and innovative solutions. Therefore, by applying existing theories and methods from the fields of mobility transition, demography in urban planning, shared mobility, mobility hubs, community engagement in the urban planning process, and the application of VR studies in urban developments, this theoretical framework helps to guide the data collection methods and the analysis of findings. This chapter reviews those topics and their key theories to help understand the rationale behind this research.

2.1 Mobility Transition and Trends

Mobility transition refers to the systematic shift from traditional car-centric transportation models to more sustainable, inclusive, and efficient mobility systems. This transition emphasizes the integration of various modes of transport, including public transit, shared mobility options, cycling, and walking, to create a balanced and environmentally friendly urban mobility ecosystem. The key components of the mobility transition include reducing reliance on private vehicles, promoting active transportation, and enhancing the accessibility and quality of public transport systems (Newman & Kenworthy, 2015).

Mobility transition is critical for addressing several pressing challenges urban areas face today. Traditional car-centric transportation systems contribute significantly to traffic congestion, air pollution, greenhouse gas emissions, and urban sprawl. These issues negatively impact public health, environmental sustainability, and the overall quality of urban life (Miner et al., 2024). By shifting to sustainable mobility solutions, cities can reduce their carbon footprint, improve air quality, and create more livable and resilient urban environments (World Bank Group, 2017).

According to Newman & Kenworthy (2015), mobility transition also supports social equity by providing more accessible and affordable transportation options for all residents, including those who do not own private vehicles. It fosters economic efficiency by reducing the costs associated with traffic congestion and vehicle maintenance. Additionally, promoting active transportation modes like walking and cycling has significant public health benefits, including reduced rates of obesity, cardiovascular diseases, and other lifestyle-related health issues (Younkin et al., 2021).

According to Nanayakkara et al. (2023) the primary goals of mobility transition include:

- **Reducing Environmental Impact**: Lowering greenhouse gas emissions and air pollution by minimizing the use of fossil fuel-powered vehicles.
- **Enhancing Public Health**: Promoting active transportation and reducing the negative health impacts of pollution and sedentary lifestyles.
- **Improving Accessibility**: Ensuring all residents can access reliable and affordable transportation options.
- **Increasing Economic Efficiency**: Reducing the

economic costs associated with traffic congestion and inefficient transportation systems.

- **Fostering Social Equity**: Providing equitable transportation solutions that cater to the needs of diverse populations.

Furthermore, an important part of any transition is the societal aspects framing, for example, how humans experience and adapt to change (Newman & Kenworthy, 2015). For example, the diffusion of Innovations Theory, proposed by Everett Rogers, describes how new ideas and technologies spread within a society. It categorizes adopters into innovators, early adopters, early majority, late majority, and laggards (Rogers, 1971). According to the theory people who adopt an innovation early have different characteristics than people who adopt an innovation later. When promoting an innovation to a target population, it is important to understand the characteristics of the target population that will help or hinder the adoption of the innovation. Therefore, understanding the diffusion process is crucial for promoting new mobility solutions. Identifying and targeting early adopters can accelerate the adoption of sustainable transport options.

The concept of mobility transition is the overarching theme guiding this research. The M4H development adheres to mobility transition principles by integrating diverse transportation modes, such as public transit, shared mobility options, cycling, and walking, to create a sustainable and efficient urban mobility ecosystem.

The recommendations for the M4H development should be guided by the primary goals of mobility transition, as outlined by Newman & Kenworthy (2015) and Nanayakkara et al. (2023), which include reducing environmental impact, enhancing public health, improving accessibility, increasing economic efficiency, and fostering social equity. By adhering to these principles, the M4H CMH can effectively contribute to creating a more livable and resilient urban environment. Thus, the theoretical framework of mobility transition not only underpins this research but also directly informs the practical strategies for developing an inclusive and sustainable mobility hub that meets the diverse needs of the M4H community.

2.2 The Role of Demography in Urban Planning

Demographic analysis is crucial in urban planning, providing essential insights for developing policies and strategies that reflect the population's needs and characteristics. Schmitt (1952)emphasizes that population analysis is central to city planning, with design standards typically based on population metrics such as size, distribution, and composition. Demography, defined by Britannica (2024) as the statistical study of human populations concerning size, density, distribution, and vital statistics (births, deaths, etc.), is integral to understanding and planning for diverse urban communities.

In the context of the M4H project, analyzing the socio-demographic backgrounds and mobility patterns of surrounding communities is essential. Detailed demographic data enables urban planners to identify and address the specific needs and preferences of different population segments through tailored urban solutions. For instance, understanding the transportation

habits of various age groups, income levels, and household compositions can inform the design and implementation of CMHs that cater to diverse needs.

Moreover, integrating detailed economic, social, and demographic data supports informed decision-making at the local level. Stefan Schweinfest, Director of the United Nations Statistics Division, highlights the importance of precise and integrated statistical information for urban planning. This comprehensive approach ensures that urban plans are both theoretically sound and practically applicable, addressing real-world challenges and opportunities in city development (Mohanta, 2022).

By leveraging demographic data, the M4H project can develop CMHs that are not only functional but also equitable, ensuring that all residents, regardless of their socio-economic status, have access to efficient and affordable transportation options.

2.3 Shared Mobility

In recent years, many cities have seen the emergence of shared mobility services. It refers to transportation services that are shared among users, providing an alternative to private car ownership. These services allow individuals to access various modes of transportation on a pay-per-use basis, often facilitated through digital platforms. The primary goal of shared mobility is to reduce the number of private vehicles on the road, thus decreasing traffic congestion, lowering emissions, and promoting more efficient use of transportation resources (Guyader et al., 2021).

Guyader et al. (2021) list several categories of services:

- **Car- sharing**: Users can rent cars for short periods, often by the hour or minute. Examples in the Netherlands include Greenwheels, MyWheels or GoSharing.
- **Bike- sharing**: Bicycle programs that allow users to borrow bikes from locations throughout a city. In the Netherlands examples include OVFiets or Donkey Republic.
- **Ride- hailing**: Services like Uber and Bolt that connect passengers with drivers who provide transportation in their personal vehicles via a mobile app.
- **Scooter- sharing**: Electric scooters that can be rented for short trips through smartphone apps. In the Netherlands, there are, for example, services like Check, Felyx, or GoSharing.
- **Ridesharing/Carpooling**: These services facilitate sharing rides among multiple passengers traveling to similar destinations. Examples include apps like BlaBlaCar.
- **Traditional car rental:** Services that offer long-term car rental, usually with a need to book in advance. An example is Bo-Rent or Sixt.

Shared mobility offers numerous benefits. One of the chapters of the book titled "*Shared Mobility*" written by Junfeng Jiao (2021) mentions, for example, its contribution to environmental sustainability. By reducing the number of private vehicles on the road, shared mobility helps lower greenhouse gas emissions and air pollution, resulting in cleaner urban air. For example, bicycle-sharing systems in cities have significantly reduced vehicle emissions (Geissinger et al., 2019).

In addition, Jiao (2021) also states that, economically, shared mobility provides significant cost savings for users.

Individuals who frequently use shared modes of transportation, such as bike sharing, experience substantial decreases in transportation expenses. According to surveys, "supersharers"—those who routinely use multiple shared modes—see a 30% decrease in net transportation spending compared to private car use. Even those who use shared mobility less frequently still experience an 18% reduction in costs (Jiao, 2021). These savings are achieved by avoiding the expenses associated with car ownership, such as maintenance, insurance, and fuel (Jiao, 2021; Sakaria & Stehfest, 2013).

Shared mobility also enhances transit equity by offering accessible transportation options to individuals who cannot afford private vehicles. This particularly benefits low-income households, as reliable transportation increases job access and promotes economic mobility. The availability of shared mobility services can fill in the gaps left by traditional public transit, especially during off-peak hours when public transportation is limited. For instance, ride-hailing has a clear peak demand during late-night hours, a time when public transit is often unavailable (Jiao, 2021).

Moreover, shared mobility provides convenience by improving established transportation modes. It offers faster alternatives to public transport, which often involves multiple stops and longer travel times. For example, bike-sharing systems can provide quicker commutes for short distances compared to buses. Additionally, shared mobility can alleviate traffic congestion, saving time and increasing overall productivity (Jiao, 2021).

However, there are also drawbacks to shared mobility. One significant limitation is the unequal distribution of benefits. Shared mobility services are usually less popular among disadvantaged communities, such as low-income. This difference can be attributed to limited knowledge, poor internet access, and lack of smartphone ownership among these groups (Jiao, 2021; Shaheen et al., 2017).

Jiao (2021) also mentions another criticism of shared mobility is the spatial bias that favors high-income neighborhoods. Companies may strategically place vehicle stations in richer neighborhoods to maximize profits, thus discriminating against low-income communities that most need affordable transit. This approach creates social inequities and limits the potential benefits of shared mobility for disadvantaged populations (National Academies of Sciences, 2016).

In addition, there are also concerns about the lack of government regulation and the potential exploitation of business morality in the shared economy. Businesses may prioritize profit over social well-being, using environmental and social causes as marketing tricks rather than genuinely contributing to sustainability and equity. To address these issues, active cooperation between governments and businesses is necessary, along with economic and non-economic incentives for companies that meet environmental and social standards (Jiao, 2021).

Finally, studies also mention that the operation of shared mobility services involves the collection and storage of large amounts of user data which is often also questioned by users in terms of digital safety and privacy (Cohen & Shaheen, 2018). Next to that, physical safety is also often mentioned as a negative factor as people tend to take less care of the vehicles due to the lack of ownership. As a result, they get

damaged and can pose threats to users (Newman & Kenworthy, 2015).

The discussion of shared mobility is directly linked to this research, which aims to explore how these innovative transportation services can be effectively integrated into the M4H CMH. The study seeks to understand the potential benefits and drawbacks of shared mobility in the context of M4H and how these services can be tailored to meet the diverse needs of future residents and workers in the area.

2.4 Community Mobility Hubs

A mobility hub is a centralized location that integrates various modes of transportation and services to facilitate seamless and efficient urban mobility. While there is a typology of mobility hubs, they typically include facilities for public transit, car-sharing, bike-sharing, and other shared mobility services, all designed to promote multimodal transport options and reduce reliance on private cars (Weustenenk & Mingardo, 2023).

While the concept of community mobility hubs is new, in M4H the focus will be placed on the needs and engagement of the local community. Unlike standard mobility hubs that primarily facilitate transport, CMHs will integrate social and economic functions to serve as local activity centers. They will serve as centralized points for various transportation services, including parking, shared mobility options, and other collective amenities such as package services, waste collection, and energy services. Those facilities will serve beyond transportation and create community and commercial opportunities in the area (APPM Management Consultants et al., 2022). Figure 6 shows a concept idea of such hubs' programming.

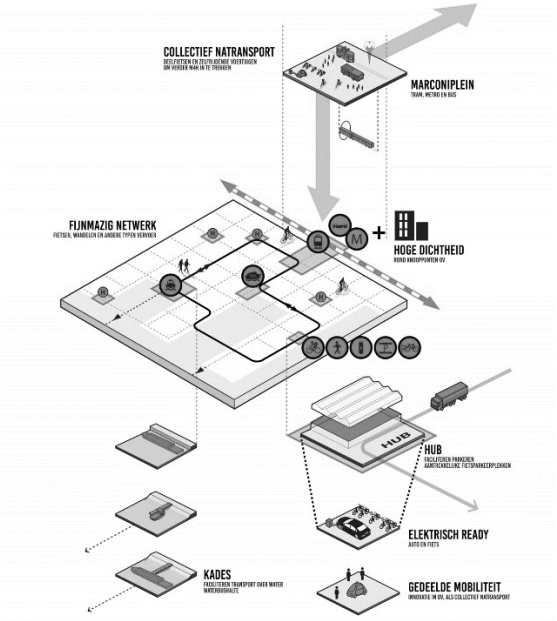


Figure 6 Community Mobility Hub Concept Design (Delva, 2019)

Principles of flexibility and adaptability will guide the design of the mobility hubs. Hubs should be constructed to accommodate changing demands, with the potential to transform into other functions as parking needs decrease (APPM Management Consultants et al., 2022).

The discussion on CMHs is linked to this research as it provides the foundation for understanding how such facilities will be designed and implemented in M4H. This description aims to explain the plans and help understand the future scenario.

2.5 Mobility Choice Aspects and Inclusivity in Urban Mobility

While many elements could describe inclusive mobility, one approach by the UK's Department for Transport (DfT) refers to transportation systems that are available, accessible, affordable,

and acceptable for all individuals, regardless of their socioeconomic status, physical abilities, or other potential barriers (pteg, 2010), in other words- follow the 4A's Inclusive Transport Framework. According to DfT, it is essential for creating equitable urban environments and ensuring that everyone has the opportunity to participate fully in societal activities (pteg, 2010).

In 4A's framework, *availability* refers to the presence of transport services when and where they are needed. *Accessibility* is the ease of reaching and using transport services, particularly for those with disabilities or limited mobility. *Affordability* is the cost of using transport services in relation to users' income. *Acceptability* measures the extent to which transport services meet users' needs and preferences (pteg, 2010).

However, there are also other travel choice attributes of traveling listed in the literature that play a crucial role in travelers' journey choices and catering to inclusive mobility. For example, **travel time** refers to the duration of a journey from start to finish. Minimizing travel time enhances the efficiency of transportation systems and improves users' quality of life (Bates et al., 2001). **Convenience** in transport is the ease and comfort of using transportation services. Convenience is critical for encouraging the use of public and shared transportation options.

Reliability in transport refers to the consistency and dependability of transportation services. Reliable transport services build user trust and ensure timely travel (Bates et al., 2001).

Comfort in transport refers to the physical and mental ease of travel. Comfortable travel experiences can increase user satisfaction and can for example encourage the use of public and shared transportation. **Safety** in transport involves the protection of users from, for example, accidents. Ensuring safety is paramount for user confidence and the attractiveness of transport services (Litman & Brenman, 2012).

Ease of use refers to how simple and intuitive it is for users to navigate and utilize transportation services. Simple and user-friendly systems encourage higher adoption rates and reduce barriers to access (Eboli & Mazzulla, 2008). **Travel experience** encompasses the overall perception and satisfaction of users during their journey. A positive travel experience is crucial for user retention and the success of transportation services (Gatersleben & Uzzell, 2007).

Environmental impact refers to the effect of transportation on the natural environment, including emissions and resource use. Reducing environmental impact is vital for sustainable development and combating climate change (Banister, 2008).

By applying the 4A's Inclusive Transport Framework and considering other crucial travel choice attributes such as travel time, convenience, reliability, comfort, safety, ease of use, travel experience, and environmental impact, this research can identify key factors that influence user satisfaction and adoption of new mobility solutions. Furthermore, this framework guides the data collection and analysis methods by emphasizing the importance of capturing diverse user travel experience attributes to better understand their travel choices.

2.6 Community Engagement and Participatory Planning

Community engagement is a crucial element in urban planning, significantly contributing to the sustainability and inclusivity of development projects. By involving community members in the planning process, urban initiatives are more likely to reflect the collective interests and needs of the population, leading to enhanced livability and functionality of urban environments. In addition, community engagement fosters a sense of ownership and responsibility among residents, which can improve the management and preservation of urban areas (Gagan Deep, 2023b).

Participatory planning, a model that emphasizes the active involvement of community members in decision-making processes, has improved the transparency and accountability of urban development projects. It ensures that diverse voices, including those from marginalized and minority groups, are heard and considered, promoting social fairness and cohesion (Gagan Deep, 2023b).

In the context of M4H, community engagement, and participatory planning are vital for ensuring that the development meets the needs of both current residents and future users. The surrounding neighborhoods' diverse socio-demographic backgrounds necessitate an inclusive planning approach. By involving community members in the design and decision-making processes, the M4H project can create a more inclusive and responsive environment.

For example, Participatory Action Research (PAR) is a collaborative research approach involving participants in various research process stages. It combines reflection, data collection, and action to address community-specific issues and promote social change (Baum, 2006). PAR is rooted in the belief that those affected by the research should have a say in how it is conducted and used.

PAR is important for several reasons:

- **Empowerment**: It empowers community members by involving them in decision-making and giving them a sense of ownership over the outcomes.
- **Local Knowledge**: It leverages local knowledge and experiences, leading to more context-specific and effective solutions.
- **Action- Oriented**: PAR is action-oriented, aiming to create real-world impacts and improvements in the community.
- **Collaborative Learning**: It fosters collaborative learning and mutual respect between researchers and participants (Baum, 2006).

The application of PAR to the M4H project involves engaging residents and stakeholders in a cycle of reflection and evaluation. This approach can help identify the specific mobility needs and preferences of the M4H community, ensuring that the CMH is designed and implemented to maximize its benefits and accessibility.

By involving community members in the planning and development of the mobility hub, the M4H project can create a more inclusive and responsive environment. This participatory approach can also help build trust and foster a sense of ownership among residents, increasing the likelihood of successful implementation and long-term sustainability.

2.7 Virtual Reality in Urban Planning

Virtual Reality refers to using computer technology to create a simulated environment that a person can explore and interact with. Unlike traditional user interfaces, VR places the user inside an experience, allowing for interaction with 3D worlds (Rauschnabel et al., 2022). VR has been increasingly used in various fields, including urban planning, due to its ability to simulate real-world scenarios and environments. In urban planning, VR is applied to visualize and evaluate urban spaces, simulate the impact of new developments, and can facilitate participatory planning processes (Azofeifa et al., 2022).

VR helps planners and stakeholders better understand the potential impacts of urban developments and facilitates more informed decision-making processes. For instance, Birrell et al. (2022) explored how VR can be utilized to capture user experiences within urban air mobility infrastructure, highlighting its ability to assess usability and gather valuable feedback.

Theoretical Insights

The theoretical foundation of using VR in urban planning lies in its ability to create highly realistic simulations that effectively communicate complex spatial information. The Extended Virtual Environment (EVE) framework, for example, provides a comprehensive structure for implementing VR in research advising on an execution plan (Grübel et al., 2017). Additionally, this framework supports the idea that VR can significantly enhance understanding of spatial relationships and urban dynamics, which are often challenging to grasp through traditional 2D plans and models.

Moreover, VR supports scenario-based planning, where multiple design options can be visualized and evaluated. This approach aligns with theoretical models of participatory planning and collaborative design, where stakeholders are actively involved in the planning process.

VR has been utilized in urban planning to achieve several objectives. For instance, it allows planners to visualize urban environments before they are built, providing a platform for stakeholders to experience proposed developments and make informed decisions (Birrell et al., 2022). VR also supports the simulation of urban mobility scenarios, helping to evaluate the efficiency and impact of various transportation systems. Moreover, it facilitates the design and testing of public spaces, ensuring that they meet the needs of diverse user groups.

Engaging Citizens Through VR

One of the most significant applications of VR in urban planning is its use as a tool for citizen engagement. Traditional public participation methods, such as community meetings and surveys, often fail to convey the full implications of urban projects. VR, however, provides an interactive platform where community members can virtually explore proposed developments and provide real-time feedback (Azofeifa et al., 2022).

By incorporating VR into participatory planning processes, urban planners can gather detailed insights into community preferences and concerns, leading to more inclusive and user-centered urban designs.

Case Study: Urban Air Mobility Infrastructure Design

A case study that illustrates the use of VR in urban planning is the design of urban air mobility infrastructure in Coventry, UK. This project used VR to

capture user experiences and evaluate the design of the world's first urban airport. The study involved 20 participants who navigated through a virtual urban airport environment, providing feedback on their experience and wayfinding. The insights gained from this VR study informed the design of future urban air mobility infrastructure, highlighting the potential of VR to enhance user experience and optimize design before physical deployment (Birrell et al., 2022).

Case Study: Pedestrian Perception of Future Street Scenarios

In a related study, Argota Sánchez-Vaquerizo et al. (2024) utilized VR to study pedestrian perception of future street scenarios. This research aimed to understand how pedestrians perceive and interact with different street designs in a virtual environment. The experiment revealed that VR can effectively capture pedestrian feedback on various aspects of street design, such as safety, comfort, and accessibility. The findings from this study underscore the value of VR in urban planning, particularly in engaging citizens and incorporating their input into the design process (Azofeifa et al., 2022).

In this study, VR added value as it allowed potential future users of M4H to immerse themselves in a hypothetical future scenario. The VR model allowed users to explore and interact with the planned environment by simulating a real-world situation, offering a tangible preview of future mobility solutions. Section 4.1 details how VR was applied in this research, including the design of the VR environment, the recruitment of participants, and the methods of data collection and analysis used to interpret the findings.

2.8 Summary

The theoretical framework for this study is grounded in several key concepts: mobility transition, the role of demography in urban planning, shared mobility, community mobility hubs, mobility choice aspects, and community engagement through participatory planning, with a significant focus on the application of Virtual Reality (VR) in urban planning. Mobility transition emphasizes shifting from car-centric transportation to sustainable, inclusive systems integrating public transit, shared mobility, cycling, and walking. The role of demography in urban planning emphasizes the need for consulting neighborhood statistics to create sound and inclusive urban plans. Shared mobility services, which include car-sharing, bike-sharing, and ride-hailing, offer environmental, economic, and social benefits but face challenges like unequal distribution and safety concerns. Community mobility hubs aim to centralize various transportation modes and services, prioritizing local community needs and fostering social and economic activities.

Inclusive urban mobility, based on the 4A's Framework (Availability, Accessibility, Affordability, Acceptability) and mobility choice aspects, can guide the design of equitable transportation systems for all individuals. Community engagement, particularly through Participatory Action Research (PAR), involves residents in planning and enhancing the relevance and inclusivity of development projects. Through frameworks like the Extended Virtual Environment (EVE), VR technology offers immersive experiences for stakeholders to visualize, interact with, and provide feedback on urban

planning proposals. This combination of theoretical insights provides a comprehensive foundation for analyzing and developing future mobility solutions in the M4H area (Figure 7), ensuring they are sustainable, inclusive, and community-centered.

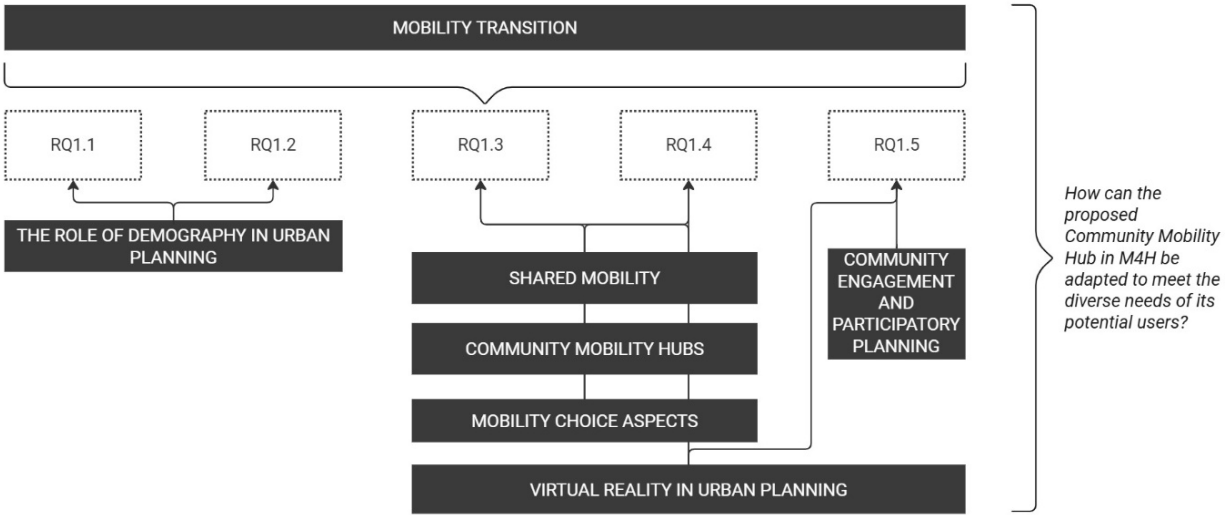


Figure 7 Theoretical Framework

PART 1: UNDERSTANDING M4H'S COMMUNITY CONTEXT

3

3. Neighborhood Analysis Methods and Results

This part of the report focuses on understanding the background of the subsequent part of this research. Building on the role of demography in urban planning, this chapter explains aspects such as demographic and socioeconomic profiles of the existing communities around M4H and their travel patterns to aid the creation of sound urban plans. Further, the findings of this section guided the design of the VR experience sessions linking them to the real-world context of communities in M4H.

The following parts explain the data collection methods (section 3.1) and present the results (section 3.2). Both elements were designed to help reach O1 and O2 and answer RQ1.1 and RQ1.2.

3.1 Methods

3.1.1 Demographic and Socio-Economic Profiles of M4H Communities

The analysis of the neighborhoods surrounding M4H was conducted to understand the socio-demographic characteristics and, thus, possible needs of potential M4H users. Recognizing the diversity in demographics and socio-economic backgrounds helps in designing equitable mobility solutions that cater to all residents' needs. This approach aligns with the principles of mobility transition, which emphasize reducing car dependency and promoting sustainable and inclusive transportation options (Newman & Kenworthy, 2015).

The goal of this research activity was to describe the residents of the neighboring areas and, thus, potential future users of the facilities in M4H. Therefore, the information analyzed during this phase consisted of demographic profiling of the residents in Nieuw-Mathenesse, Oud Mathenesse (including Witte Dorp), Spangen, Tussendijken, and Bospolder—areas surrounding M4H.

This desk research part of the study was based on reviewing data on websites such as AlleCijfers.nl and Onderzoek010.nl, which provide information based on open data. The information reviewed included the residents' age, household composition, employment sector, income, and housing type.

Additionally, during this part of the study, on-street observations were conducted to understand the behavior of people present in the area and documented with photographs for review and reporting.

3.1.1 The Primary Mobility Patterns of M4H Communities

Understanding the mobility patterns of the residents is crucial for identifying the community's current transportation habits and preferences. This information is vital for tailoring the CMHs to address these needs effectively. By examining how residents currently move around and what modes of transportation they use, the study can propose solutions that meet the community's needs (Guyader et al., 2021).

Data from the Onderweg in Nederland (ODiN) study was analyzed to

understand the mobility patterns in and around M4H and to realize the potential mobility needs of its future residents.

ODiN aims to gather comprehensive data on the daily mobility patterns of the Dutch population to support the Ministry of Infrastructure and Water Management, as well as other policy and research entities. It is a continuous national-level study that tracks the travel behavior of Dutch residents daily and delivers yearly overviews. Participants report their travel details for a specific day, including destinations, purposes, transportation modes, and travel durations. Additional questions cover topics such as (electric) bicycle ownership, average transport usage, education, and social status (Centraal Bureau voor de Statistiek, 2023).

For this research, ODiN data was requested and downloaded through the DANS portal- the national repository for research data (DANS, n.d.). To increase the accuracy of the results, the three most recent datasets (from 2020, 2021, and 2022) were analyzed. The data was combined and filtered for records from participants living in the areas surrounding M4H: Nieuw-Mathenesse, Oud-Mathenesse (including Witte Dorp), Spangen, Tussendijken, and Bospolder.

The data was analyzed using descriptive statistics in RStudio and Excel. This analysis aimed to explore the modes, trip purposes, trip durations, and trip destinations of the residents of the mentioned areas—their current mobility patterns and habits. This helped to understand the potential mobility needs of future users.

3.2 Results

In M4H's development plans, a few target groups are listed (Chapter 1.1.1). While some will only be attracted to the area upon completion of the project, others are already present. This section explains the demographic and socio-economic profiles (section 3.2.1) and the current mobility patterns of the current residents of M4H and the surrounding neighborhoods (section 3.2.2). Key insights are provided in section 3.2.3. Understanding these elements can help guide the CMH's recommendations that respect the needs of this target group.

3.2.1 Demographic and Socio-Economic Profiles of M4H Communities

This part of the report presents the summarized demographic and socio-economic profiles of M4H Communities. A full analysis report can be found in Appendix B.

3.2.1.1 Nieuw-Mathenesse

Nieuw-Mathenesse is the neighborhood where new plans are made for the M4H area. Currently it is an industrial area with shipping functions, offices, and test sites. At this moment there are not many people living in Nieuw-Mathenesse. Records showed approximately 1100 inhabitants in 2022.

Figure 8 Nieuw-Mathenesse Location (Google Maps)


Figure 9 Nieuw-Mathenesse

The dominant age group among the residents of Nieuw-Mathenesse is 27-39 years old (61%), followed by 18-26 years old (26%) and 40-54 years old (7%). Most households in Nieuw-Mathenesse are single-person households (61%), with two-person households making up 34%.

Nieuw-Mathenesse has a diverse population, with many residents coming from Asian (32%) and European (30%) backgrounds. The majority of people in Nieuw-Mathenesse are employed in consulting, research, and other specialist business services (24%). Some residents work in public administration (17%) or wholesale and retail trade (16%).

Almost all properties in Nieuw-Mathenesse are private rental properties (99.8%), and nearly all are multi-family houses with elevators (97.1%), such as the Lee Towers, or other multi-family dwellings.

In summary, despite its industrial character, the neighborhood has approximately 1100 inhabitants as of 2022, with a diverse demographic composition. Dominated by single-person households and two-person households, Nieuw-Mathenesse reflects a mix of cultural backgrounds, with residents primarily employed in consulting, research, and specialist business services. Housing primarily comprises private rental properties, with multi-family dwellings like Lee Towers being a notable landscape feature. There was no information available on Nieuw-Mathenesse resident's income.

3.1.1.1 Oud-Mathenesse

Oud-Mathenesse is a neighborhood just north of M4H. It is characterized by vibrant, walkable streets, greenery, playgrounds, and a visible presence of community engagement.

Figure 10 Oud-Mathenesse Location (Google Maps)

Figure 11 Oud-Mathenesse

Oud-Mathenesse is a neighborhood characterized by a youthful population, with the age groups of 27-39 years (27%), 40-54 years (20%), and 18-26 years (18%) being the most prevalent. This makes it a neighborhood with a significant number of young residents.

The majority of households in Oud-Mathenesse are single-family households, accounting for 60% of the population. There are also some double households (18%) and couples with children households (11%).

The neighborhood is diverse, with many residents having European migration backgrounds (28%), followed by those with Dutch (27%) and Surinamese (8%) backgrounds.

Most people living in Oud-Mathenesse work in the education sector (21%). This is followed by employment in the wholesale and retail sector (16%) and the health and welfare sectors (15%).

Economically, the majority of households in Oud-Mathenesse are low-income (61%), with some mid-income (34%) and high-income (5%) households also present.

Oud-Mathenesse is predominantly a youthful neighborhood with a significant number of single-family households, alongside double and couples with children households. It reflects a diverse demographic with European, Dutch, and Surinamese backgrounds. The housing mainly consists of multi-family dwellings without elevators, and private rental properties are the most common type. Employment is mainly in the education sector, followed by wholesale and retail, and health and welfare sectors.

3.1.1.2 Witte Dorp

Witte Dorp is a small area often considered together with Oud-Mathenesse. Historically it was built for the workers of the Merwe-Vierhavens port. Currently, it is a quiet place with little traffic and a sense of community visible on the streets.

Figure 12 Witte Dorp Location (Google Maps)

Figure 13 Witte Dorp

The majority of the population in Witte Dorp is between 40 and 54 years old (21%), with a significant share of people above 65 (18%). Additionally, there is a notable portion of residents aged 27-

39 (15%). Most households in Witte Dorp are single-family households (37.5%), followed by two-parent family households (32%).

The population in Witte Dorp is predominantly of Dutch origin (32%), with sizable communities of Moroccan (20%) and Turkish (17%) backgrounds. Most housing in Witte Dorp consists of corporate rentals (73%) or owner-occupied properties (25%), and nearly all housing is single-family (96.6%).

Employment data for Witte Dorp residents is varied, with many professions not specified. However, a significant share of residents work in wholesale and retail trade (19.2%). The majority of households in Witte Dorp are low-income (61%), although there is also a substantial portion of middle-income households (39%).

In summary, Witte Dorp has a predominantly older population, with a significant number of residents over 40 years old, including a large portion above 65. The area features primarily single-family households, with a mix of Dutch, Moroccan, and Turkish residents. Housing is mainly corporate rentals and owner-occupied properties, predominantly single-family homes. The employment landscape is diverse, with a notable presence in wholesale and retail trade. Socio-economically, the area is characterized by a majority of low-income households, with a substantial middle-income segment.

3.2.1.2 Spangen

Spangen is a vibrant area with many green spaces, vibrant shopping streets, playgrounds, and a large share of families with children. Some sports facilities in this neighborhood attract people from surrounding areas.

Figure 14 Spangen Location (Google Maps)

Figure 15 Spangen

In Spangen, the majority of residents are aged 27-39 (22%), followed by those aged 40-54 (20%) and 18-26 (15%). The neighborhood also has a significant share of children and teenagers, with 23% of the population being 17 years old or younger. Most households are either single-person households (45%) or two-parent families (24%).

The population in Spangen is predominantly of Dutch origin (19%), with substantial communities of Moroccan (18%) and Turkish (18%) backgrounds. Housing in Spangen is primarily corporate rental properties (60.8%), and the majority of the housing consists of multi-family units (93.1%).

Employment data for Spangen residents shows a diverse range of sectors, though many are unspecified. Notable employment sectors include health and welfare (21.3%), public

services (13.7%), and consulting, research, and other specialist business services (10.2%). Most households in Spangen are low-income (65%), with a portion of middle-income (29%) and some high-income households (6%).

In summary, Spangen is characterized by a diverse demographic, with significant numbers of residents in the 27-39, 40-54, and 18-26 age groups, as well as a notable presence of children and teenagers. Household compositions are mainly single individuals or two-parent families. The population includes a mix of Dutch, Moroccan, and Turkish backgrounds. Housing is largely corporate rentals, with multi-family units being predominant. The employment landscape is varied, with significant representation in health and welfare, public services, and consulting sectors. Socio-economically, Spangen is primarily low-income, with some middle- and high-income households.

3.1.1.3 Tussendijken

Tussendijken is a vibrant area with playgrounds and a lot of people present on the streets. It is dense yet green.

Figure 16 Tussendijken Location (Google Maps)


Figure 17 Tussendijken

Most residents of Tussendijken are aged 27-39 (23%), followed by those aged 40-54 (18%) and 18-26 (17%). There is also a significant number of children up to 17 years old (18%) and elderly residents over 65 (12%). The majority of households are single-family (55%), with other common household types being two-parent families (16%) and double-parent households (15%).

The population in Tussendijken is predominantly of Dutch origin (22%), with considerable representation from Moroccan (18%), Turkish (15%), and other European backgrounds (14%). Most housing in Tussendijken is corporate rental (60%), followed by private rental (27%) and owner-occupied residences (12%). The housing landscape is mainly multi-family dwellings (97%).

Employment among Tussendijken residents spans various sectors, with many working in fields not specified in the data. Notable sectors include education (17.8%), health and welfare (16.2%), wholesale (13.1%), and consulting (12.9%). The majority of households are low-income (73%), with a share of middle-income (23%) and some high-income households (5%).

In conclusion, Tussendijken presents a diverse demographic landscape with significant representation across various age groups, including young

adults, children, and elderly residents. Single-family households are predominant, followed by two-parent families and double-parent households. The neighborhood is culturally diverse, with residents of Dutch, Moroccan, Turkish, and other European origins. The housing is mainly corporate rental properties, with a mix of private rentals and owner-occupied homes, primarily consisting of multi-family dwellings. Employment sectors are varied, with notable presence in education, health, welfare, consulting, and wholesale trade. While most households are low-income, there is a notable proportion of middle and high-income households, contributing to the socioeconomic diversity of Tussendijken.

3.1.1.4 Bospolder

Bospolder is a lively neighborhood with many activities on the streets. There are shopping streets, playgrounds, community centers, and a visible presence of community engagement. For example, Figure 19 shows an interaction between neighbors and their children on one of the streets.

Figure 18 Bospolder Location (Google Maps)


Figure 19 Bospolder

Most residents of Bospolder are aged 27-39 (29%), followed by those aged 40-54 (19%) and 18-26 (16%). The neighbourhood also has a significant number of children up to 17 years old (19%). The predominant household type in Bospolder is single-family (49.4%), followed by two-parent families (20.5%) and double households (16.2%).

The population is mainly of Dutch origin (23%), with considerable representation from Moroccan (18%), Turkish (17%), and other European backgrounds (11%). Housing in Bospolder primarily consists of corporate rental properties (62.2%), with private rentals (21.2%) and owner-occupied residences (15.6%) also present. Most homes are multi-family dwellings (91%), with a smaller proportion of single-family homes (7%).

Employment in Bospolder is concentrated in the wholesale and retail trade sector (30%), followed by consulting and research (12%) and health and welfare (12%). The majority of households are low-income (67%), with a share of middle-income (26%) and some high-income households (6%).

In summary, Bospolder is characterized by a diverse demographic, with a strong presence of young adults, children, and middle-aged residents. Single-family

households are the most common, followed by two-parent families and double households. The neighborhood is culturally diverse, with significant Dutch, Moroccan, Turkish, and European populations. Housing is predominantly corporate rental properties, mostly comprising multi-family dwellings. The local workforce is largely engaged in wholesale and retail trade, consulting, research, and health sectors. Socioeconomically, while Bospolder is mainly low-income, there is a notable presence of middle and high-income households, contributing to the neighborhood's diversity.

Key Insights

In conclusion, the common characteristics of these neighborhoods are a large share of the young population (the majority aged 27-39 years old), families with children, and single-person households. There is a large population of residents with migrant backgrounds making these neighborhoods culturally diverse. The analysis showed that the households across all neighborhoods were mostly low-income. Observing the neighborhoods in person showed that there is a strong sense of community and many activities taking place on the streets.

3.1.2 The Primary Mobility Patterns of M4H Communities

Understanding users' current mobility habits can also help create future mobility scenarios that suit their needs. This section explains the key elements of mobility patterns occurring in Nieuw-Mathenesse, Oud-Mathenesse (and Witte Dorp), Spangen, Tussendijken, and Bospolder, a detailed analysis can be found in Appendix C.

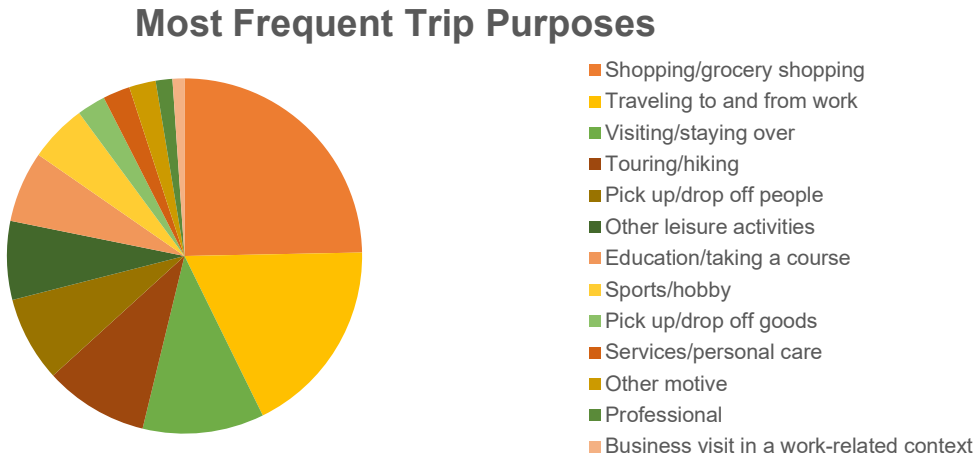


Figure 20 Most Frequent Trip Purposes Across M4H Communities

Across all records in the data set, the most frequent trip purposes were shopping/ grocery shopping (25%), traveling to and from work (18%), visiting/staying over (11%), and touring/hiking (9%). Other frequent purposes include picking up/ dropping off people (8%), leisure activities (7%), education (6%), and sports (5%).

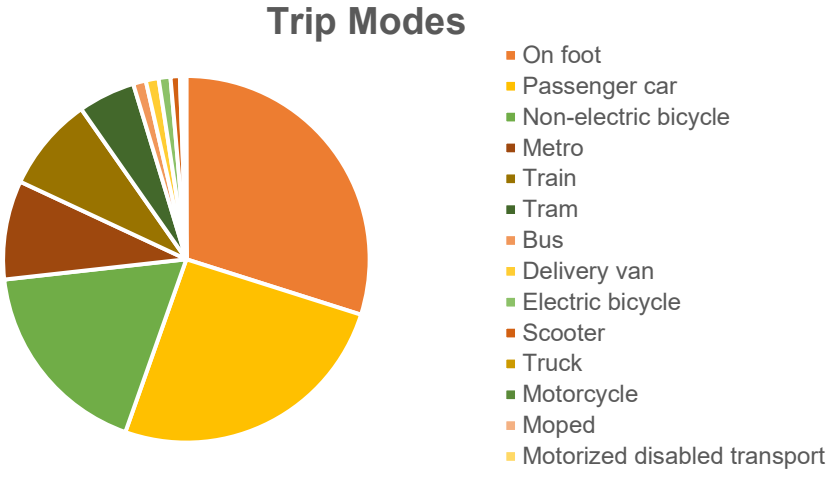


Figure 21 Trip Modes Across M4H Communities

Some of the most frequent modes of travel for people living in the M4H neighborhoods are walking (30%), passenger car (26%), bicycle (18%), metro (9%), train (8%), and tram (5%). Other less frequent modes are buses, delivery vans, electric bicycles, or scooters (all around 1%).

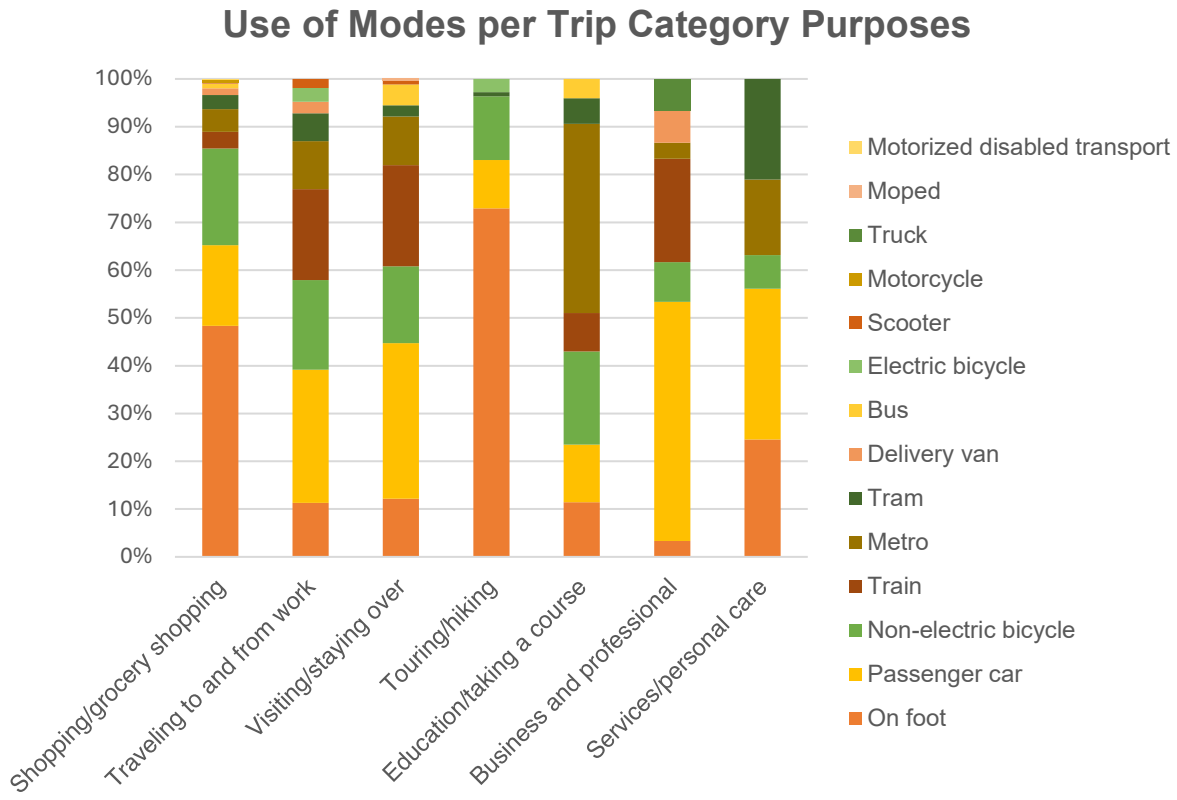


Figure 22 Use of Modes per Trip Purposes Across M4H Communities

For the most frequent trip purposes, the following modes are used:

- *Shopping: traveling on foot (48,3%), passenger car (16,8%), non-electric bicycle (20%).*
- *Work trips: passenger car (27,8%), train (19%), non-electric bicycle (18,8%).*
- *Visiting/ staying over: passenger car (32,5%), train (21%), non-electric bicycle (18,8%).*
- *Touring/hiking: traveling by foot (73%), non-electric bicycle (13,3%), passenger car (10%).*

Additionally, the metro is used most frequently for educational trips, and cars and trains are used most often for business trips. For services and personal care, walking, driving a car, or taking a metro or tram are most frequent.

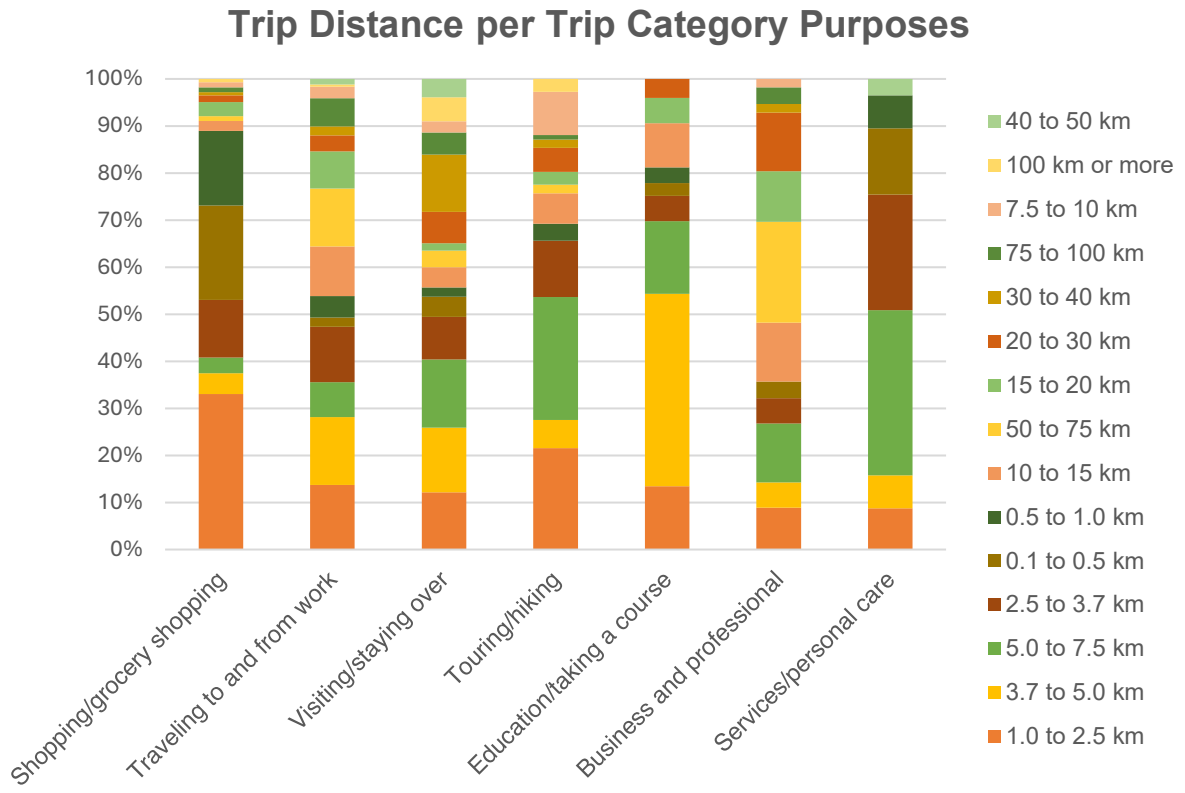


Figure 23 Trip Distance per Purpose Across M4H Communities

For shopping trips mostly short distances are covered (0.1-2.5km) (33%). For work trips, there is a big dispersion in distances, with most occurrences for 1 -2.5km (13,7%), 2.5-3.7km (11,8%), 3.7- 5km (14,4%), 10-15km (10,6%), and 50- 75km (12,3%)- traveled. Visiting/staying over trips cover short distances from 1-7.5 (40%) or long-distance trips between 30-40km (12%). Touring/hiking trips mostly cover 1-2.5km (22%) or 5-7.5km (26%).

Key Insights

The analysis of trip data from neighborhoods surrounding M4H in Rotterdam shows insightful patterns in travel behaviors and preferences. Shopping, commuting to work, visiting/staying over, and touring/hiking emerge as the most frequent trip purposes, indicating residents' diverse range of activities in and around M4H. The mode of transport varies significantly based on trip purpose, with walking, passenger cars, bicycles, and public transportation being commonly used.

Destination-wise, most trips remain within the same neighborhood or neighboring areas, with occasional journeys to the city center of Rotterdam, Delft, Schiedam, or Utrecht. Shopping trips predominantly target local areas with retail facilities, while work-related trips often extend to Rotterdam's city center or neighboring districts.

The analysis also shows the correlation between trip purposes, modes of transport, and household compositions. For instance, households with children exhibit a higher frequency of picking

up/dropping off people, while households with couples, children, and additional occupants prioritize touring and hiking trips. Households with couples and other occupants perform a lot of professional trips. Education trips have the highest share among single-parent households compared to other household types.

Income levels also influence travel behaviors. For example, lower—and mid-range-income households tend to engage in longer-distance trips.

Moreover, trip duration and timing show distinct patterns, with most trips lasting between 30 and 45 minutes and peak travel times occurring during 9:00 -12:00 and 14:00 -16:00, coinciding with shopping, work-related, and leisure activities.

3.1.3 Part 1 Insights

Analyzing socio-demographic data and mobility patterns offered insights into the characteristics and behaviors of residents in and around M4H. By examining variables such as household compositions, income levels, trip purposes, modes of transportation, trip distances, and demographic and socioeconomic profiles, the mobility needs of potential users of the M4H CMH can be addressed.

Across Nieuw-Mathenesse, Oud-Mathenesse, Witte Dorp, Spangen, Tussendijken, and Bospolder, there is a diverse demographic landscape. These neighborhoods are characterized by a blend of age groups, with a significant presence of young adults aged 18-39, families with children, and elderly individuals. Household compositions vary, with single-person households, couples with children, and single-parent families being prevalent. Moreover, the population represents a mix of cultural backgrounds, including Dutch, European, Moroccan, and Turkish origins. Socioeconomically, low-income households are dominant (RQ1.1).

The mobility patterns analysis shows that residents engage in various travel purposes. Most frequent trips include shopping, commuting to work, visiting/staying over, and touring/hiking. Modes of transportation vary based on trip purposes, with walking, cycling, passenger cars, and public transport being commonly used. Trips primarily remain within the neighborhoods or nearby areas, with occasional journeys to the city center or nearby districts for work or leisure activities. Households with specific compositions show distinct travel behaviors, such as higher frequencies of professional trips among households with couples and additional occupants. Income levels also influence travel behaviors, with lower and mid-range-income households engaging in longer-distance trips for work purposes (RQ1.2).

Having addressed RQ1.1 and RQ1.2, which explore the demographic and socioeconomic profiles of the communities around M4H and their mobility patterns, the following sections will focus on the next phase of the research. The insights gathered from the initial socio-demographic analysis have provided a foundational understanding of the diverse population and their varied transportation needs and behaviors.

Part 2 will delve into user feedback on the current plans for the CMH, focusing on how different user groups perceive these plans (RQ1.3), their recommendations for additional features or services (RQ1.4), and the effectiveness of VR in enhancing citizen engagement in urban planning processes (RQ1.5). By integrating the demographic, socio-economic and mobility data from Part 1 with immersive VR simulations and user feedback, Part 2 aims to provide a comprehensive and nuanced perspective on developing CMHs that cater to the diverse needs of the M4H community.

PART 2: M4H IN VIRTUAL REALITY– CITIZEN PARTICIPATION

4

4. VR Experience Methods and Results

This part of the report focuses on the VR experience building upon the findings of Part 1. Having understood the socio-demographic composition of the neighborhoods around M4H and the mobility patterns of communities in those areas, this part of the research aimed at designing the VR experience sessions in such a way that they can be compared to the current situation. Furthermore, in this part of the research understanding the concepts of mobility transition, shared mobility, community mobility hubs, mobility choice aspects, community engagement and participatory planning, and the application of virtual reality in urban planning is crucial (Chapters 2.1-2.7). The definition of shared mobility helps to connect current solutions to the possibilities and plans for M4H. The description of the general approach to the design of community mobility hubs grounds the ideas for CMH in M4H in already existing plans. Mobility choice and inclusivity aspects help to understand how users make mobility choices and what could be the aspects important for a successful CMH adaptation. Furthermore, the collaborative PAR approach, involving participants in various research process stages, helps to engage communities in planning and emphasizes the advantages of involving citizens in creating inclusive future plans. Finally, the application of VR creates a unique opportunity to engage with communities and test an innovative approach to citizen engagement.

The following sections explain the data collection methods through the VR experience sessions (section 4.1) and present the results (section 4.2). Both elements were designed to help reach O3, O4 and O5 and answer RQ1.3, RQ1.4 and RQ1.5.

4.1 Methods

4.1.1 Virtual Reality Experiment Sessions

VR technology allows users to interact with a simulated environment, offering a realistic preview of future mobility solutions. This method effectively gathers detailed feedback on user experiences, preferences, and potential concerns. Research highlights the importance of utilizing VR-assisted studies to understand future scenarios and potential human behaviors (Brookes et al., 2020). Such studies can help understand human responses to new situations and their personal experiences and perceptions (Riegler et al., 2021).

In this study, VR experience sessions were used to allow users to experience the CMH scenario and subsequently reflect on future plans. The VR sessions were conducted in parallel with ongoing activities linked to the collaboration of the Municipality of Rotterdam, Deloitte, and MINI. As mentioned earlier in this report, Deloitte's VR environment was developed to communicate and engage with potential stakeholders about commercial possibilities for MINI, particularly representing additional vehicle (UCVs) functions.

As M4H serves as a test and pilot site for the project, the model also represents a concept for one of the CMHs to be placed in M4H. While the plan is to implement a network of hubs of different sizes, some large facilities will host parking, commercial, and communal functions. One of the existing buildings that will be turned

into a CMH is the Europoint Parking at Galvanistraat. Due to its accessible location and existing parking capacity, this building was deemed suitable to become one of the first CMH facilities (APPM Management Consultants et al., 2022) and was used as a reference in Deloitte's VR model.

This created an opportunity to use the VR model as a research tool. The VR experience sessions consisted of several elements to gather comprehensive data: quantitative data on participants' mobility preferences, feedback on the proposed solutions, and in-depth qualitative insights from semi-structured interviews about their experiences and perceptions.

By integrating these methods, the research aimed to provide a comprehensive understanding of potential users' needs and preferences, ensuring that the proposed mobility solutions are practical and suited to their needs. The following sections explain this approach in detail.

4.1.2 Session Design

The sessions were conducted in a municipal building at Marconistraat 1 in Rotterdam. Each session consisted of five elements listed in Table 2 and lasted approximately 2 hours. It followed the Framework for Experiments in Virtual Environments (EVE) designed by Grübel et al. (2017) to ensure a clear structure and correct data collection during the sessions. Figure 24 shows the adapted framework of the advised protocol showing each execution step.

A detailed overview of the sessions' agenda can be found in Appendix E.

VR Session Element	Description
1. Consent	Upon arrival, participants read and signed consent forms. **This research was approved by the TU Delft Human Research Ethics Committee (no. ID 4063) on April 16, 2024. All participants were asked to sign consent forms (Appendix D) prior to starting the session. To ensure anonymity throughout the whole session, participants were asked to use ID numbers assigned to them randomly upon arrival.*
2. Briefing	Short presentation explaining the purpose of the session and research context.
3. Pre-VR Experience Questionnaire	A questionnaire asking about participants' demographic and socio-economic backgrounds, mobility patterns, and attitudes towards shared and future mobility solutions.
4. VR Experience	A moment during which the participants stepped into the VR to experience the future mobility scenario.
5. Post-VR Experience Questionnaire	Questionnaire asking about attitudes, likelihood to adopt and general reflection on the presented scenario.
6. Focus Group	An interview with all participants to conclude the session.

Table 2 VR Experience Sessions Elements

4.1.1 Participant Recruitment and Sampling

To gather a group of people representing the future users of M4H as closely as possible, the recruitment procedure focused on reaching people who **live in or close to M4H, work in or close to M4H, or visit M4H frequently**. In addition, it was important that the participants represent the socio-demographic profiles of residents of neighborhoods surrounding M4H that were analyzed in Part 1.

This was done by (1) sending e-mails to companies located in M4H about this research and inviting the employees to participate. In addition, a similar (2) message was posted on the Inside Rotterdam Makers District platform (*an innovation community based in M4H)*, which functions as a place to share ideas, ask for help, or invite others to contribute to initiatives in the Makers District in Rotterdam.

Moreover, (3) twenty posters and fifty flyers in Dutch and English (Appendix F) informing about the research and inviting to participate were distributed around M4H and surrounding areas. People interested in the research could scan a QR code to register online through the Qualtrics platform (facilitation provided by TU Delft).

Finally, a few participants were reached through (4) a personal network of people living in Rotterdam who knew others living in and around M4H.

4.1.2 M4H CMH in Virtual Reality

During the sessions, two Meta Quest 3 headsets borrowed from the Mobility in Extended Reality Lab at TU Delft were used. Meta Quest 3 is a wireless headset equipped with two controllers. During this study, the participants only used one of them to navigate through the virtual environment. Each participant's experience was cast and recorded on a laptop for a later review. This allowed comfort of use for the participants and ease of tracking for research.

When experiencing Deloitte's VR model, participants had the chance to step into the Europoint parking, turned into the future mobility hub with additional functions. Figures 25 and 26 show the facility in its current state and transformed into a CMH in the VR model.

Figure 24 Europoint Parking Garage- Future CMH Location

Figure 25 Europoint Parking- Future Scenario (Deloitte)

The experience was designed in a sedentary mode, allowing participants to sit and observe without walking. This also created a safer research environment. Movement through the VR scenes was enabled by clicking on

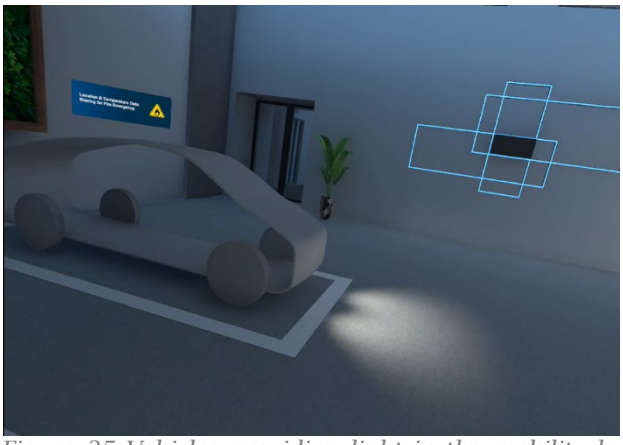
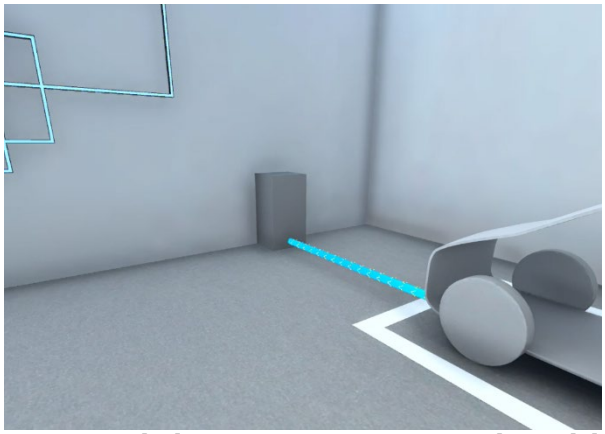
the “move to the next location" buttons. Participants were encouraged to follow the storyline and explore the environment as much as the software allowed. This included looking at different parts of the hub and reading explanations of various features and functions of shared vehicles (UCVs) parked in the garage (Table 3), all while a background voice narrated the scenario. Each participant followed the same story. Such an experience lasted on average 7 minutes.

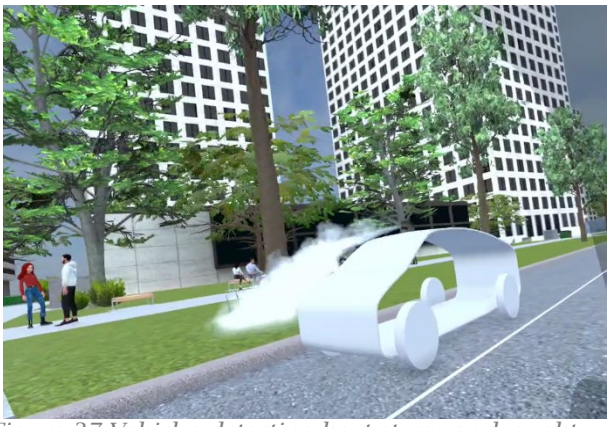
Table 3 Features Presented in the VR Scenario

Feature	Description	Graphical Representation
Shared mobility services	The hub offers an opportunity to access diverse modes of transport in one location. Users can borrow vehicles for their trips using an app.	 *Figure 26 Shared Mobility Services (Deloitte)*
Cafe	There is a cafe offering drinks and tables to sit with others.	 *Figure 27 Café (Deloitte)*

Feature	Description	Graphical Representation
Hairdresser	Users can access a hairdresser. Users can access a hairdresser.	 *Figure 28 Hairdresser (Deloitte)*
Co-working space	There is a co-working space where visitors can work with colleagues or use office supplies.	 *Figure 29 Co-working Space (Deloitte)*
A gym	Visitors can access a gym.	 *Figure 30 Gym (Deloitte)*

Feature	Description	Graphical Representation
Postal services	Users of the hub can make use of the parcel wall to easily pick up or send their packages.	 *Figure 31 Postal Services (Deloitte)*
Refurbishing center	The center is where one can borrow tools, use the workshop, or have their items fixed.	 *Figure 32 Refurbishing Centre (Deloitte)*
Ridesharing	Users can share rides with other people travelling in the same direction. Shared rides can be booked in an app.	 *Figure 33 Ridesharing (Deloitte)*

Feature	Description	Graphical Representation
Vehicles detecting fire hazards from batteries	These vehicles detect hazards that can cause accidents, such as battery ignition. They share the data to prevent accidents.	 *Figure 34 Vehicle Detecting Fire Hazards from Batteries (Deloitte)*
Vehicles providing light in the mobility hub	These vehicles use their own lights and power to provide light in the mobility hub's garage. Thus, there is less need to install additional lights at the facility.	 *Figure 35 Vehicles providing light in the mobility hub (Deloitte)*
Vehicles powering amenities in the mobility hub	These vehicles power the grid using the energy stored in their batteries. For example, this vehicle powers the coffee corner in the Community Mobility Hub.	 *Figure 36 Vehicles powering amenities in the mobility hub (Deloitte)*

Feature	Description	Graphical Representation
Vehicles detecting heat stress or draught and hydrating soil	These vehicles can detect heat stress in the city and harvest rainwater. In drought conditions, they can also hydrate soil.	 *Figure 37 Vehicles detecting heat stress or draught and hydrating soil (Deloitte)*

Deloitte and MINI selected the hub features based on previously conducted co-creation sessions with a commercial purpose separate from this research. Therefore, it was not possible to tailor the features to the context of this study.

4.1.3 Data Collection

The VR experience sessions consisted of three data collection moments: (1) a pre-VR experience questionnaire, (2) a post-VR experience questionnaire, and (3) a focus group, all specifically designed and tailored to this research by the researcher with no influence of MINI or Deloitte.

Additionally, each participant's experience was cast on a screen and recorded; however, after reviewing, there were no significant results for this study. Due to the design of the VR scenario, where each participant followed the same path and storyline, there were no significant differences between different recordings from which any conclusions could be drawn. For example, all participants spend the same amount of time looking at features and listening to the narrative. It was not possible to link the duration of a participant's gaze at a feature and their opinion about the feature in the questionnaire.

The Pre-VR Experience Questionnaire focused on collecting information about the participants' demographic backgrounds, mobility patterns, attitudes towards and experiences with shared mobility, and their perceptions and expectations of future mobility solutions in M4H based on a short briefing about the future development and brochures about the development that were available for the participants to read upon arrival. The questionnaire consisted of 27 open, closed, multiple-choice, Likert scale, ranking, and matrix questions. The questions were designed to collect information that could later be compared to the data from M4H's neighborhood analysis. For example, questions were structured similarly to the data from the Onderzoek010.nl platform and ODiN data, following the same categories, variables, and value choices. This data was collected to understand the participants' profiles, check for representativeness with the communities around M4H, and further inform about future users' current habits and patterns. The full version of the questionnaire can be seen in Appendix G.

The Post-VR Experience Questionnaire asked participants to reflect on the VR experience. The questions focused on collecting information about changes in ideas and perceptions about the mobility plans for M4H after experiencing VR. Personal views on the presented features, the likelihood of adoption, perceived usefulness and importance of those features, the impact of those features on aspects of traveling, and ideas for changes in the future scenario were also considered. In addition to that, the questionnaire also asked about the experience of VR in general and if participants experienced any discomfort. This questionnaire consisted of 14 open, closed, multiple-choice, Likert scale, and matrix questions. It was based on mobility choice and inclusive mobility aspects. This data was collected to gather feedback and understand the receptivity to the proposed solutions. The full version of the questionnaire can be seen in Appendix H.

Both questionnaires were made available in a digital format on the Qualtrics platform. During each session, four tablets borrowed from the municipality of Rotterdam were handed out to the participants to complete the questionnaires.

The last step of the session, the focus group discussion, was guided by a list of 12 questions (Appendix I) and aimed at gathering a deeper understanding of participants' emotional responses, detailed feedback, and suggestions

regarding the VR scenario of future mobility solutions in M4H. It worked as a supportive element for the questionnaire responses. Each focus group was audio-recorded for a later transcription.

4.1.4Analysis of Results

After the sessions, the results of the questionnaires were downloaded from Qualtrics in a .csv format and analyzed using RStudio and Excel. The quantitative data analysis focused on descriptive statistics to identify trends, patterns, and significant differences among various user groups. The following steps were undertaken for the quantitative analysis:

1. **Data Cleaning:** The raw data from Qualtrics was first cleaned to remove any incomplete or invalid responses. This ensured that the analysis was based on accurate and reliable data.

2. **Descriptive Statistics:** Basic statistical measures such as mean and frequency distributions were calculated to summarize the participants' demographics, mobility preferences, and feedback on the VR experience.

3. **Comparative Analysis:** Comparative analyses were conducted to examine differences in responses across different demographic groups (e.g., age, gender, income, household composition, and relation to M4H) and to identify any significant variations in mobility preferences and perceptions.

4. **Correlation Analysis:** Correlations were calculated to explore relationships between different variables, such as the correlation between participants' demographic backgrounds and their feedback on the proposed mobility hub features.

Additionally, the open-ended questions were coded with ATLAS.ti. This involved a detailed thematic analysis (TA) to identify common themes, patterns, and insights from participants' qualitative responses (Braun & Clarke, 2012). The following steps were undertaken for the qualitative analysis:

1. **Transcription and Coding:** The focus group recordings were transcribed using TurboScribe software and manually corrected to ensure accuracy. The transcriptions were then imported into ATLAS.ti for coding.

2. **Thematic Analysis:** The qualitative data were coded using a thematic analysis approach. This involved identifying key themes and sub-themes related to participants' experiences, perceptions, and suggestions regarding the future mobility hub.

3. **Pattern Identification:** Patterns and trends within the qualitative data were identified by grouping similar codes together. This helped us understand participants' common concerns, preferences, and suggestions.

4. **Contextual Analysis:** The qualitative data was analyzed in the context of the quantitative findings to comprehensively understand participants'

feedback. This involved cross-referencing qualitative insights with quantitative trends to draw meaningful conclusions.

By integrating these methods, the analysis provided a comprehensive understanding of the potential participant's feedback and receptivity to the proposed solutions. The next sections present the results.

4.2 Results

Conducting the VR experience sessions allowed to gather additional data about the future M4H users: people currently living or working in or around M4H and people visiting the area frequently.

There were six sessions, each with 2 to 4 participants. Twenty-two participants participated in the VR experience sessions.

Figure 38 Participant Experiencing the VR Scenario

This chapter examines the demographic and socio-economic profiles of VR experience sessions participants (section 4.2.1) and their mobility patterns (section 4.2.2). Next, it explains their perceptions of proposed solutions (section 4.2.3) and the differences across demographic groups (section 4.2.4). Then, it gives an overview of alternative solutions proposed by the participants (section 4.2.5) and their reflections and feedback after the experience (section 4.2.6). Finally, section 4.2.7 presents the impact of VR in this study. The chapter provides key insights in section 4.2.6.

4.2.1 Participants' Demographic and Socio-Economic Profiles

The age distribution among participants was balanced, with seven participants aged 18-26, nine participants aged 27-39, and six participants aged 40-54.

The study included seven females and fifteen males. Additionally, six of the participants were first-generation migrants, two were second-generation migrants, thirteen had no migrant background, and one preferred not to disclose the information.

The household composition among participants varied, reflecting different living situations. Five participants reported living as a couple, six as couples with children, five lived alone, three lived with housemates, and three reported other living arrangements.

In terms of household income, five participants fell into the lower 40% income bracket, thirteen were in the middle 40% bracket, three were in the top 20% bracket, and one participant preferred not to disclose their income.

The participants' connections to M4H area were also diverse. Three participants lived in M4H, nine lived in neighborhoods close to M4H, four worked in M4H, two frequently visited M4H, and four had other types of connections to the area.

Key Insights

Overall, the demographic profile of the participants highlights a range of ages, genders, migrant backgrounds, household compositions, income levels, and connections to the study area. While this sample is not fully representative of findings on demographic and socio-economic characteristics of people living in neighborhoods around M4H (only age categories reflecting the population in the neighborhoods), the findings can still be valuable as the majority of the participants (18 of the 22) are representative of the M4H development's target groups. In addition, 8 of the 22 of the participants are of migrant background. Even though this number is not representative of the real context they provide useful insight for this research. Finally, although the participants' household compositions are not fully representative of the context, the high share of couples with children, couples, and people living alone also provides insights into those groups' preferences, also widely present around M4H. Overall, this diversity is crucial in providing a holistic understanding of the receptivity to the proposed CMH features

4.2.2 Participants' Primary Mobility Patterns

4.2.2.1.1 General Habits

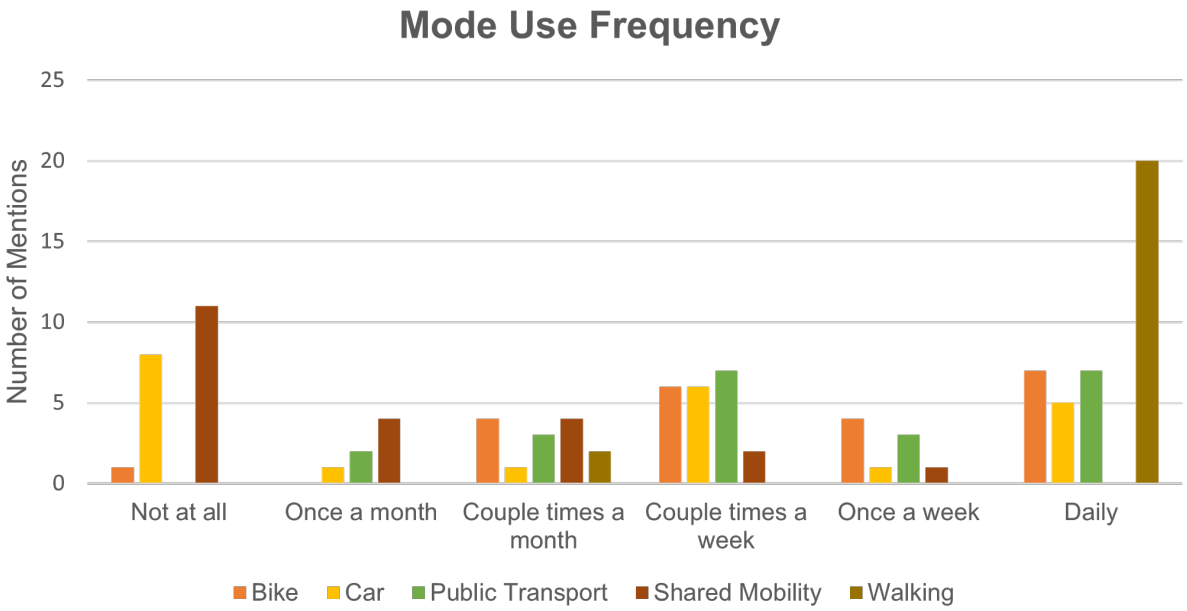


Figure 39 Figure 40 Mode Use Frequency, VR Experience Participants

Participants reported varying frequencies in their use of different transportation modes (Figure 40), reflecting a diverse range of mobility habits.

Bicycles were a popular mode of transport, with one participant not using a bicycle at all, while four used it a couple of times a month, six a couple of times a week, four once a week, and seven participants used bicycles daily. Car usage showed a different pattern, with eight participants not using a car at all, one using it once a month, one a couple of times a month, six a couple of times a week, one once a week, and five participants using cars daily.

Public transport usage was moderately frequent; two used it once a month, three a couple of times a month, seven a couple of times a week, three once a week, and seven daily. Shared mobility options were less frequently used, with eleven participants never using shared mobility, four using it once a month, four a couple of times a month, two a couple of times a week, and one using it once a week. Walking was a common mode of transport, with twenty participants walking daily. Two participants indicated they only walk a couple of times a month.

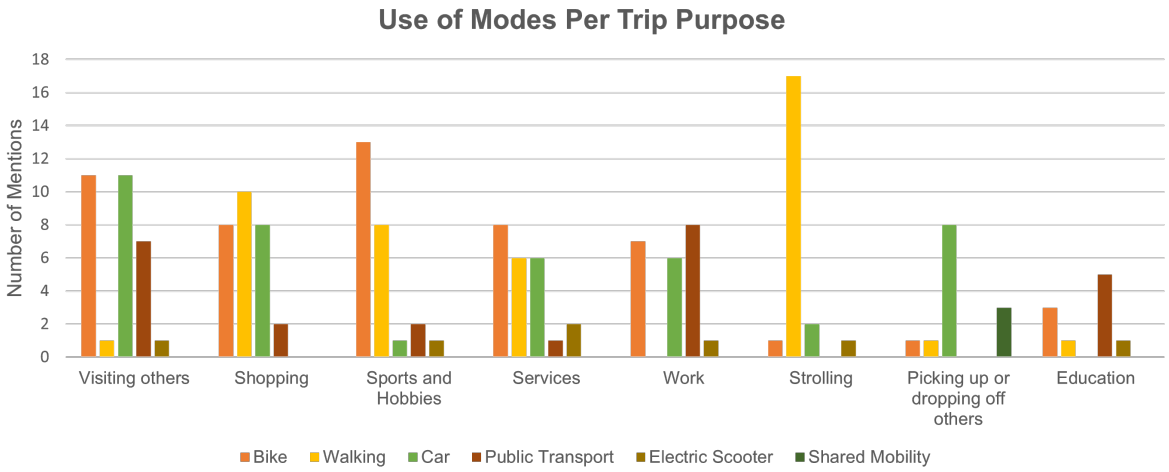


Figure 40 Use of Modes per Trip Purpose, VR Experience Participants

Participants also used different modes of transport for various purposes (Figure 41). For visiting others, bicycles (11 participants), cars (11 participants), and public transport (7 participants) were the most common modes. When it came to shopping, participants primarily used walking (10 mentions), bicycles (8 participants), and cars (8 participants). For sports and hobbies, bicycles (13 participants) and walking (8 participants) were the primary modes of transport. Services were accessed via bicycles (8 participants) and walking (6 participants) and cars (6 participants). Public transport (8 participants) and bicycles (7 participants) were the main modes of commuting to work. Strolling destinations were predominantly reached on foot (17 participants). Picking up and dropping off others was reported to be done by car (8 participants) and on rare occasions by bike or walking (1 participant). Education trips were primarily made by bicycles (3 participants) and public transport (5 participants).

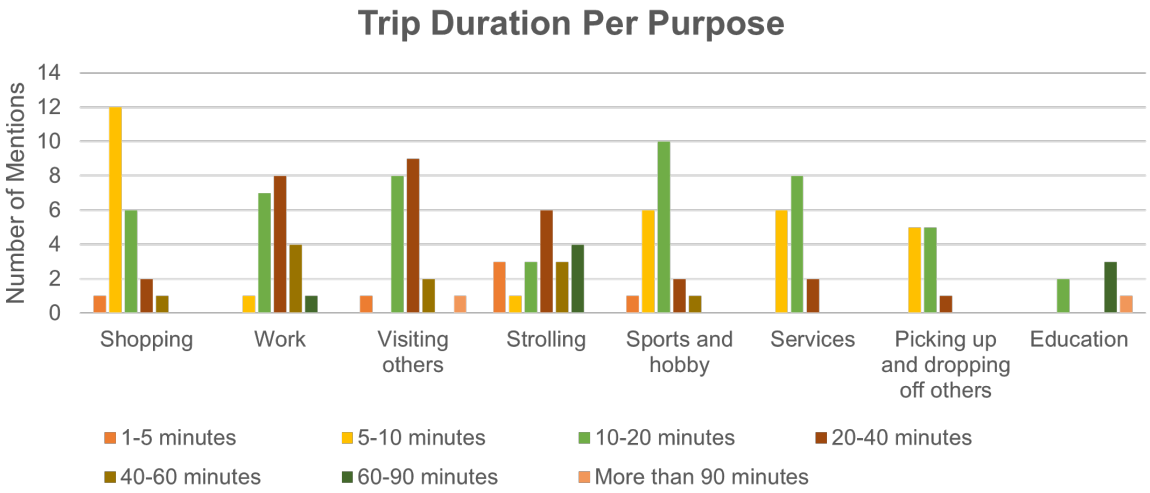


Figure 41 Trip Duration per Purpose, VR Experience Participants

The duration and distance of trips (Figure 42) varied depending on the purpose. Most shopping trips were short, with twelve participants reporting durations of 5-10 minutes. Work commutes varied, with most lasting between 10-20 minutes (7 participants) and 20-40 minutes (8 participants). Visits to others were typically 10-20 minutes (8 participants) and 20-40 minutes (9 participants) long. Strolling durations were diverse, ranging from 20-40 minutes (6 participants) and 60-90 minutes (4 participants). Most trips for sports and hobbies lasted 10-20 minutes (10 participants) and 5-10 minutes (6 participants). Service trips were generally 5-10 minutes (6 participants) and 10-20 minutes (8 participants) long. Majority of picking up and dropping off others trips were 5-10 minutes (5 participants) or 10-20 minutes (5 participants). The majority of education trips are 60-90 minutes or more (3 participants).

When asked about the most important aspects of choosing modes of transportation the participants listed travel time, affordability, and convenience as the three top priorities. On the other hand, unreliability, long travel time, and inconvenience were listed as barriers they currently face in their daily commutes.

When asked about their preferred mode of travel for their daily commutes in an ideal situation, they indicated walking as their first choice, followed by biking, public transport, private cars, shared mobility, and option 'other' at the end. Interestingly, one 24-year-old female participant listed option 'other' as the third choice and explained it as an "electric moped."

4.2.2.1.2 Shared Mobility Usage

During the session participants were also asked to provide their experience with shared mobility.

Participants used various shared mobility options, and each participant could indicate several modes used. Shared bikes were the most commonly used, with thirteen participants reporting their use. Eleven participants used shared mopeds, seven participants used shared cars, and three participants used shared cargo bikes. Four participants had never used any shared mobility options.

Several key features of shared mobility services were highly valued by participants who have used these services before, each participant could list an unlimited number of features. Convenience was highlighted as a crucial feature by thirteen participants. Ease of use was important to twelve participants, while availability, reliability, and travel time were valued by nine participants each. Affordability was mentioned eight times. Accessibility was considered important by six participants, and four participants noted the environmental impact as a valued feature. Comfort and travel experience were each mentioned by three participants, while safety was noted by one participant.

Those participants who never used shared mobility (4) also identified several barriers (participants could select as many barriers as desired) that hindered their use of shared mobility options. The complexity of use was cited as a barrier by three participants, and inconvenience was mentioned by three as well. Two participants reported a lack of comfort, and two noted poor availability of shared mobility options. Additional barriers included not having a driver's license (one participant), poor accessibility (one participant), and unreliability (one participant). Moreover, during group interviews, participants often mentioned that it is difficult to trust shared vehicles because, as a non-owner, you do not know their condition, and it can be dangerous. A frequent visitor of M4H mentioned,

"One time I was driving a shared moped the brakes fell out. It was very dangerous"

and it made her more hesitant to use shared mobility.

Key Insights

Participants reported diverse mobility habits, with varying frequencies of transportation mode usage. Bicycles were a common choice, with daily use by seven participants, and only one participant did not use a bicycle at all. Car usage was less uniform, with eight participants not using cars and five using them daily. Public transport had moderate usage, with daily use by seven participants and occasional use by others. Shared mobility was the least frequently used, with eleven participants never using it and only one participant using it weekly. Walking was the most consistent mode of transport, with twenty participants walking daily.

Participants used different transport modes for various purposes: bicycles, cars, and public transport were commonly used for visiting others; bicycles, cars, and walking for shopping; bicycles and walking for sports and hobbies; and public transport and bicycles for commuting to work. Trip durations varied, with most shopping trips being short (5-10 minutes), while work commutes and visits to others ranged from 10-40 minutes. Participants prioritized travel time, affordability, and convenience

when choosing transportation modes, while unreliability, long travel times, and inconvenience were major barriers. When asked about their ideal mode of travel for daily trips, participants preferred walking, followed by biking, public transport, private cars, and shared mobility.

Regarding shared mobility, shared bikes were the most used, followed by shared scooters, cars, and cargo bikes. Convenience, ease of use, availability, reliability, and travel time were highly valued features of shared mobility services by those who have used it before. Controversially, those who had never used shared mobility before mentioned barriers such as complexity of use, inconvenience, lack of comfort, poor availability, and poor accessibility.

Additionally, the VR study's results can be seen as representative in terms of general trends and common modes of transportation compared to the communities around M4H. The results of the two studies show some overlap, particularly in the common modes of transportation (walking, cycling, cars, public transport) and the frequency, time, and distances of main trips (shopping, commuting to work).

4.2.3 General Perceptions of the Proposed Solutions

The post-VR reflection phase of the study provided insights into participants' perceptions of the proposed mobility solutions. This phase focused on gauging the concept's attractiveness, perceived negative impacts, likelihood of using various features of the mobility hub, importance of specific vehicle functions, and potential impact of these solutions on different aspects of traveling.

Participants were asked to rate the attractiveness of the concept after experiencing the VR simulation (Figure 43). The majority found the concept somewhat attractive (8 participants) or neither attractive nor unattractive (7 participants). A smaller number of participants found the concept extremely attractive (3 participants) or somewhat unattractive (4 participants). None of the participants perceived the concept as extremely unattractive. This distribution indicates a generally positive receptivity, with room for improvement to enhance the concept's appeal further.

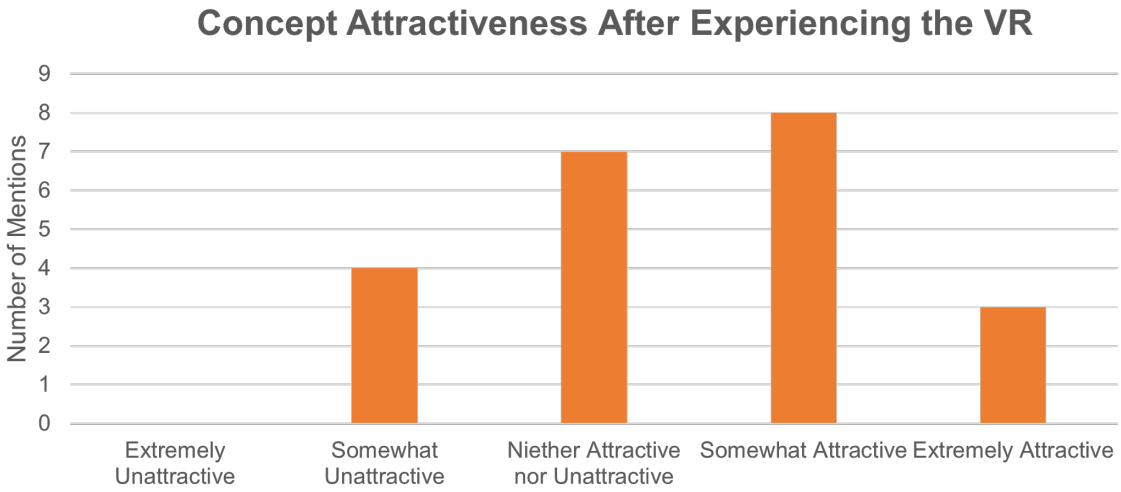


Figure 42 Concept Attractiveness After Experiencing the VR

Participants identified several potential negative impacts of the proposed solutions on mobility choice aspects. Affordability was the most significant concern, cited by 13 participants. Reliability (11 participants) and availability (9 participants) were also major concerns. Other issues included safety (6 participants), accessibility (5 participants), comfort (4 participants), ease of use (4 participants), travel experience (4 participants), travel time (4 participants), convenience (2 participants), environmental impact (1 participant), and other concerns (digital dependency) (2 participants).

Additionally, one participant noted,

"After experiencing the VR scenario, I see the potential benefits of shared mobility hubs more clearly, such as reduced traffic and better access to services. However, I still have concerns about the reliability and availability of shared vehicles, especially

during peak times" (resident of a neighborhood close to M4H). Another participant was particularly skeptical about the concept of mobility hubs located within walking distance and mentioned that such a facility would only be interesting if there were solutions to travel directly from a front door to the mobility hub to access all the features. As a person currently working in the area, he mentioned, *"The only thing that I am interested in is... Can it [shared vehicle] also pick me up? Now I have to walk to a hub".* Later in the conversation, it became clear that this option would be especially important for people with limited abilities and people who especially value the freedom of having their own vehicle parked in front of the house and ready to use at any time.

The results indicated a strong preference for the use of certain amenities (Figure 44), with Cafes, postal services, refurbishing centers,

and the mobility hub itself on average rating as 'Somewhat Likely' (4 on the scale). These features are anticipated to be the most frequently utilized by users, highlighting their importance in the daily lives of the community. Co-working spaces, gyms, ride-sharing services, and shared mobility options were also favorably rated, each with an average likelihood of 3- 'Neither Likely nor Unlikely', suggesting moderate use. The hairdresser service received the lowest average rating of 2- 'Somewhat Unlikely', indicating it is the least likely to be used by participants. These insights can guide the prioritization of features to include in the mobility hub.

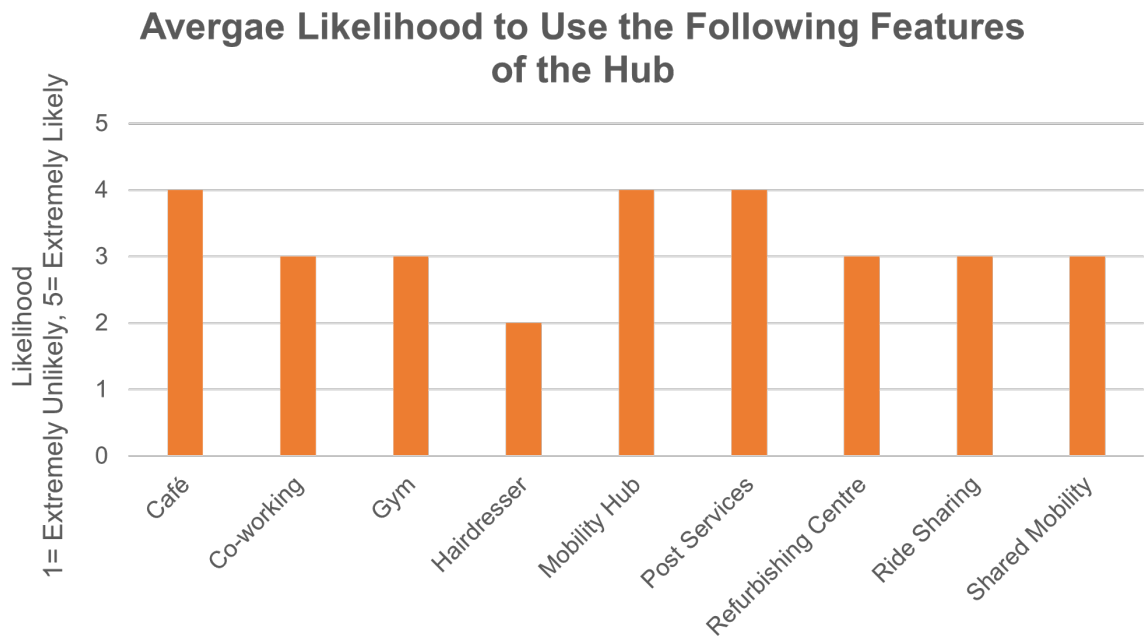


Figure 43 Average Likelihood to Use the Features of the CMH

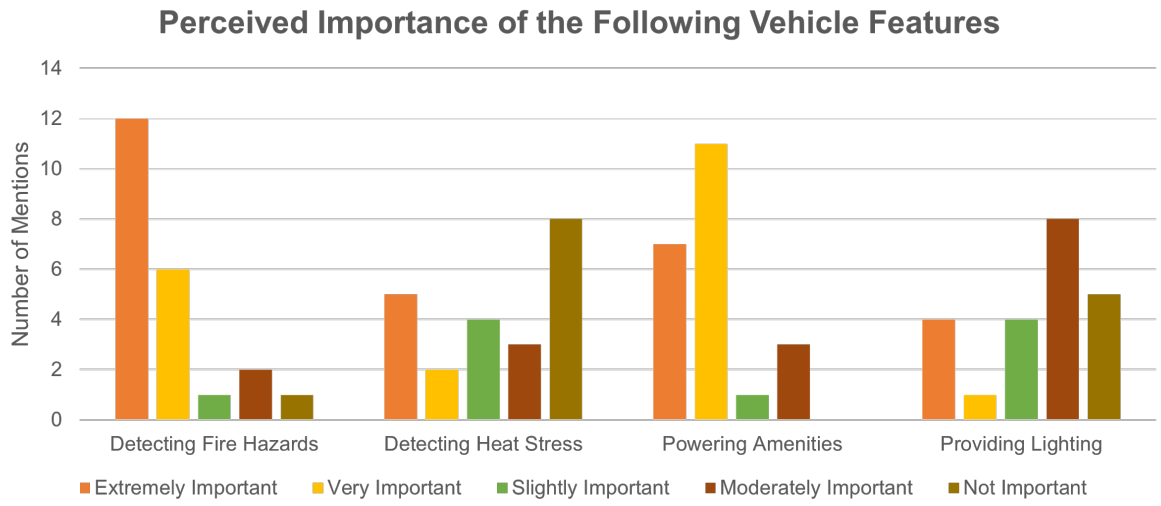


Figure 44 Perceived Importance of UCV Features

Participants also assessed the importance of specific shared vehicle features (UCVs) (Figure 45). Twelve participants deemed detecting fire hazards extremely important, followed by powering amenities (11 participants). Other participants also mentioned these features as very important. On the other hand, detecting heat stress (8) and providing lighting (5) in the mobility hub were often mentioned as not important features. Providing lighting was considered moderately important by 8 participants. Other ratings for these features varied, indicating different priorities among participants for vehicle functionalities.

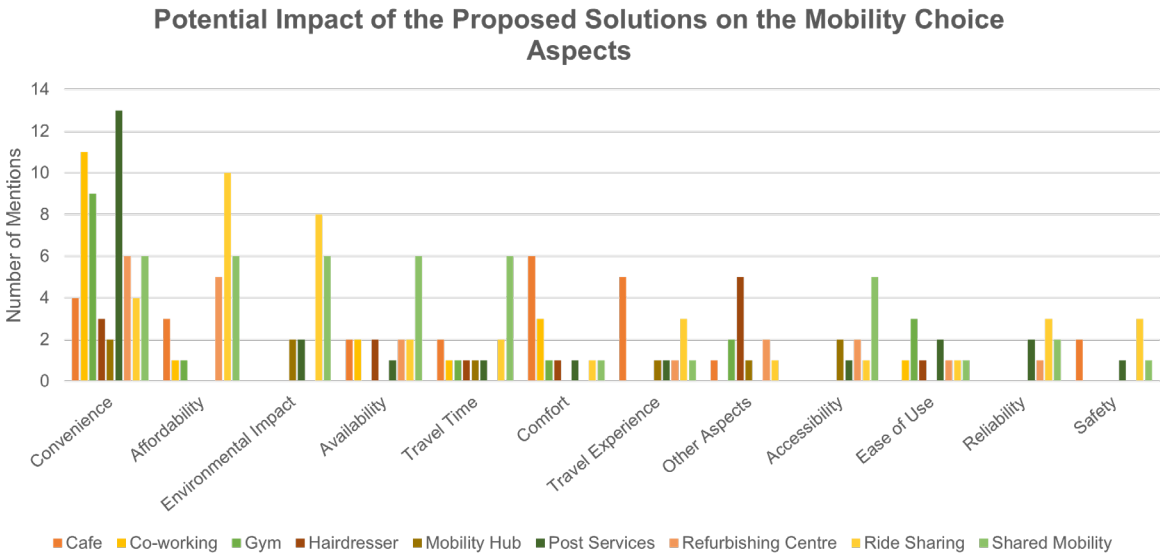


Figure 45 Potential Impact of the Proposed Features on Aspects of Travelling

Participants rated convenience as the most relevant aspect of CMH's impact on mobility choice (Figure 46), with a total of 58 mentions, indicating that participants highly value solutions that simplify their travel experience. For example, postal services were highlighted for their convenience (13

mentions) and affordability (6 mentions).

Affordability was another significant factor, with a total of 26 mentions across different features. Ride-sharing services, in particular, were noted for their affordability (10 mentions) and availability (8 mentions). This suggests that cost-effective and readily available solutions are crucial to participants.

Availability was mentioned 18 times, reflecting the importance of having accessible and reliable services. Shared mobility options and ride-sharing services were particularly mentioned in this regard with an emphasis on *"if implemented correctly"* (6 and 8 mentions, respectively).

Environmental impact was a less frequently mentioned aspect, with 18 total mentions, indicating a moderate level of concern among participants. Features like the refurbishing center were noted for their positive environmental impact (5 mentions).

Comfort and travel time were also significant, with 14 and 15 mentions respectively. The gyms were particularly noted for their comfort (7 mentions), while postal services were appreciated for their efficient impact on travel time (e.g. saving the amount of trip segments) (2 mentions).

Other aspects such as travel experience, ease of use, reliability, safety, and accessibility received fewer mentions but were still important to certain participants. Travel experience had 12 mentions, with Cafes being a notable feature in enhancing the overall experience (6 mentions). Ease of use was mentioned 10 times, reliability 8 times, safety 7 times, and accessibility 11 times.

In summary, the data indicates that participants would appreciate convenience, affordability, environmental impact, and availability when it comes to the proposed mobility solutions. While travel time and comfort are also important, they were not indicated as results of the proposed solutions.

Key Insights

The post-VR reflection phase revealed valuable insights into participants' perceptions of the proposed mobility solutions experienced through Virtual Reality. Participants generally found the concept somewhat attractive, with the majority rating it as somewhat attractive or neither attractive nor unattractive, though some found it extremely attractive. Key concerns identified included affordability, reliability, and availability, followed by issues such as safety, accessibility, comfort, and ease of use. These findings indicate aspects that need improvement to enhance the acceptability of the proposed solutions.

Participants strongly preferred certain amenities within the mobility hub, such as cafes, post services, refurbishing centers, and the mobility hub in general. Other features like co-working spaces, gyms, ride-sharing services, and shared mobility options were moderately rated, while hairdresser services were the least likely to be used. Convenience emerged as the most frequently mentioned aspect, emphasizing the need for solutions that simplify travel experiences. Affordability and availability were also crucial for ride-sharing and shared mobility options. Overall, participants prioritize **convenience, affordability**, **environmental impact**, and **availability**, suggesting these areas should be the focus of enhancing the mobility hub's effectiveness and user satisfaction.

4.2.4 Perceptions of the Proposed Solutions per User Group

This section presents the perceptions of various user groups regarding the current plans for the M4H CMH. The research identified distinct user groups based on migrant background, gender, household composition, income, and their relation to M4H (living in M4H, living in a neighborhood close to M4H, working in M4H, visiting M4H, and others). These groups were selected for analysis as they were deemed relevant to compare the cultural diversity, specific household compositions, and generally low-income levels characteristic of the neighborhoods surrounding M4H. Additionally, understanding the relationship of different groups to M4H is crucial for assessing the potential perceptions and needs of the development's target users. By analyzing feedback from these diverse groups, this section aims to provide a comprehensive understanding of how different segments of the community view the proposed mobility solutions. These insights are essential for tailoring the CMH Hub to meet its future users' unique needs and preferences, ensuring that the hub is inclusive and effectively serves the entire M4H community.

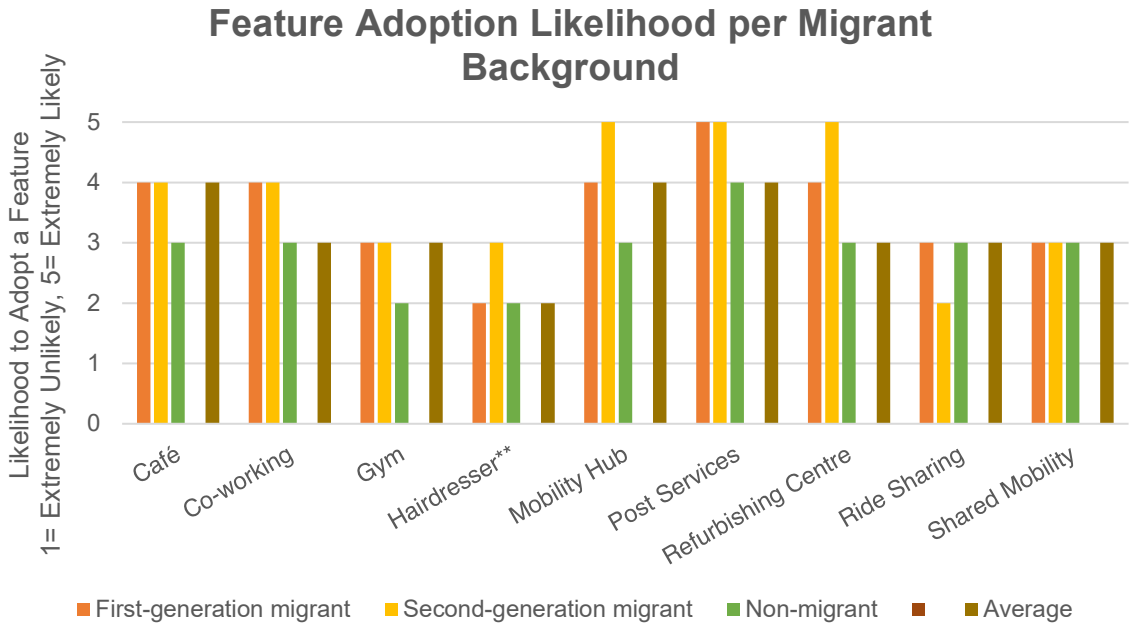


Figure 46 Feature Adoption Likelihood per Migrant Background
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

First-generation migrants showed a high likelihood of using Cafes, co-working spaces, mobility hubs, post services, refurbishing centers, and shared mobility, each rated at 4 (somewhat likely), with post services rated at 5 (extremely likely). Gyms and ride sharing were rated at 3 (neither unlikely nor likely), while hairdresser was rated at 2 (somewhat unlikely). Second-generation migrants had similar preferences, with high

likelihood ratings for Cafes, co-working spaces, post services, and refurbishing centers, each rated at 4 (somewhat likely). Gyms, ride-sharing, and shared mobility each received an average rating of 3 (neither unlikely nor likely), while hairdressers were rated at 2 (somewhat unlikely). Participants with no migrant background rated their likelihood of using Cafes, co-working spaces, gyms, post services, and refurbishing centers at 3 (neither unlikely nor likely), with gyms rated slightly higher at 4 (somewhat likely). Hairdressers and ride sharing were less likely to be used, each rated at 2 (somewhat unlikely). Overall, Cafes, co-working spaces, post services, and refurbishing centers are among the most likely features to be adopted, particularly by first- and second-generation migrants. At the same time, the hairdresser is a generally less likely feature to be used across all groups. Participants who preferred not to include the information where excluded from this part of the analysis.

The results of the ANOVA tests for each adoption feature based on migrant background are presented below:

Feature	Correlation	P-value
Cafe	0.667	0.527
Co-working	1.574	0.236
Gym	0.946	0.409
Hairdresser	3.671	0.047*
Mobility Hub	2.355	0.119
Post Services	0.532	0.594
Refurbishing Center	0.853	0.437
Ride Sharing	2.071	0.151

Feature	Correlation	P-value
Cafe	0.667	0.527

If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Key observations

- **Hairdresser** shows a statistically significant difference in adoption likelihood based on migrant background ($p < 0.05$). Second-generation migrants are more likely to adopt these services compared to first-generation migrants and individuals with no migrant background.

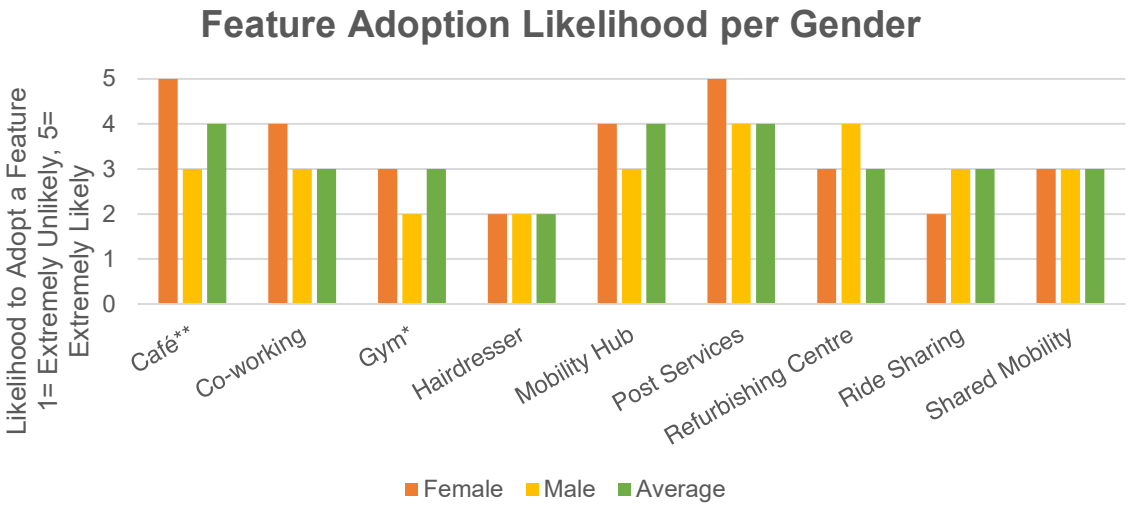


Figure 47 Feature Adoption Likelihood per Gender
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Overall, female participants were likelier to adopt features such as cafes and post services, each rated at 5 (extremely likely). They also showed a higher likelihood of using co-working spaces, the mobility hub, and refurbishing centers, each rated at 4 (somewhat likely). Male participants had a slightly lower likelihood of adopting these features, with the highest likelihood for post services, rated at 4 (somewhat likely). Both genders rated gyms, ride-sharing, and shared mobility similarly, mostly at 3 (neither unlikely nor likely). Hairdressers were rated as somewhat unlikely to be used by both genders, with a rating of 2.

The biserial correlations between gender and the adoption likelihood of different features are presented below. This includes both the correlation coefficients and their respective p-values.

Feature	Correlation	P-value
Cafe	0.612	0.002**
Co-working	0.140	0.535
Gym	0.446	0.037*
Hairdresser	-0.359	0.101
Mobility Hub	0.353	0.107
Post Services	0.394	0.070
Refurbishing Center	0.011	0.962
Ride Sharing	-0.343	0.118
Shared Mobility	0.043	0.848

If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Key observations

- **Cafe** shows a significant positive correlation with gender, indicating females are more likely to adopt cafes compared to males.
- **Gym** also shows a significant positive correlation, suggesting females are more likely to adopt gyms.
- The other features do not show significant correlations with gender at the 0.05 level.

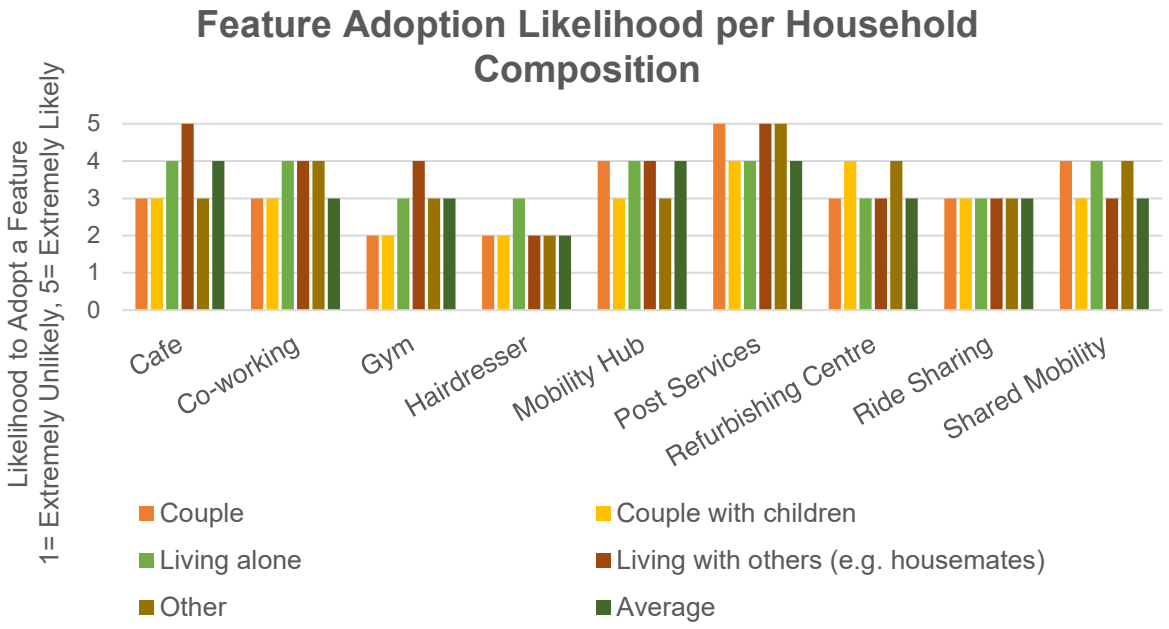


Figure 48 Feature Adoption Likelihood per Household Composition

Couples showed a high likelihood of using mobility hubs, post services, and shared mobility, with ratings of 4 or 5. Couples with children were highly likely to use postal services and refurbishing centers. These households are less likely to use gyms or hairdressers. Individuals living alone showed the highest interest in using the hairdresser among all groups, although the score was still 'neither likely nor unlikely'. This group is also among scoring highest for using the Cafe and shared mobility. Those living with others (e.g., housemates) showed a high likelihood of using cafes and the highest of all interest in using the gym- somewhat likely. They are also highly likely to use co-working spaces, mobility hubs in general, postal services, refurbishing centers, and ride-sharing, with many features rated at 4 or 5. Participants in other household compositions showed a particularly high likelihood of using postal services, each rated at 5.

The results of the ANOVA tests for each adoption feature based on household composition are presented below:

Feature	Correlation	P-value
Cafe	1.691	0.198
Co-working	0.910	0.480
Gym	1.209	0.343
Hairdresser	1.123	0.379
Mobility Hub	0.375	0.823
Post Services	1.052	0.410
Refurbishing Center	0.264	0.897
Ride Sharing	0.218	0.925
Shared Mobility	0.522	0.721

If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Key Observations

Despite the average results showing differences in likelihood, none of the p-values are below the typical significance level (0.05), indicating that there are no statistically significant differences in the adoption likelihood of the various features based on household composition.

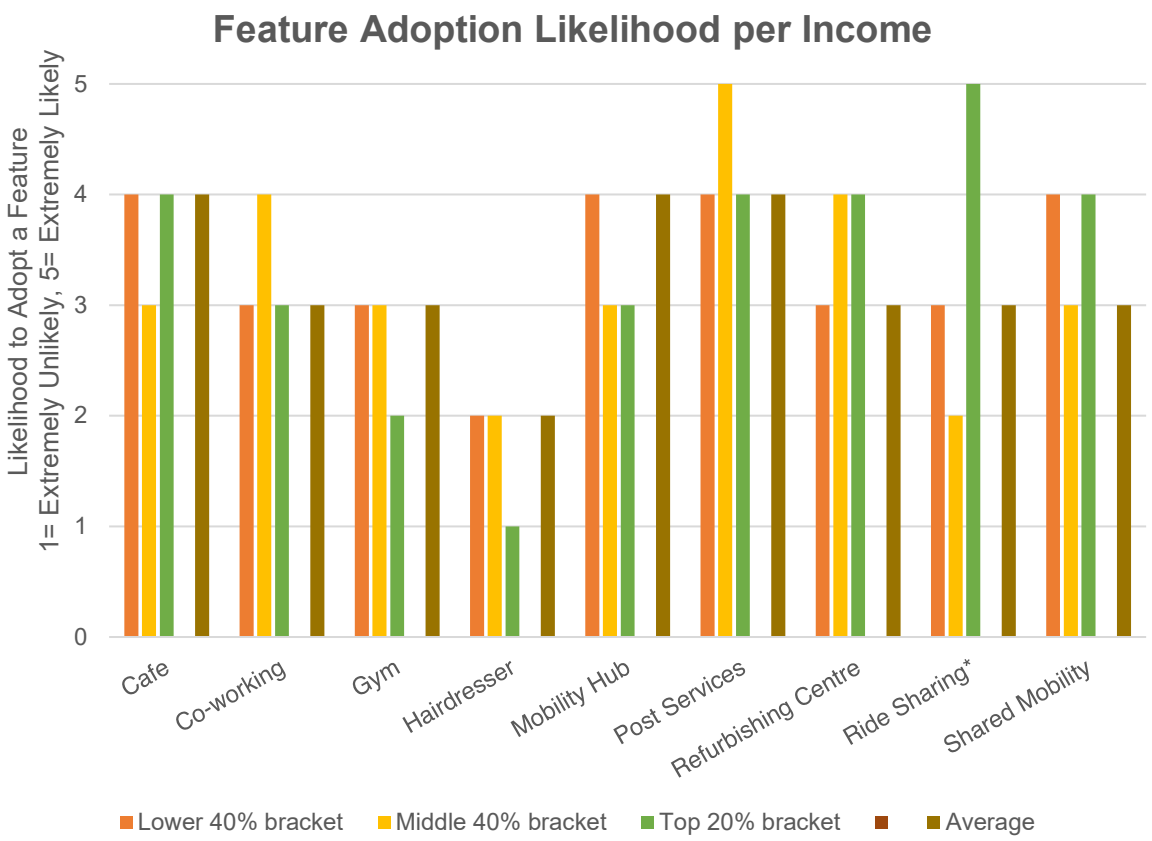


Figure 49 Feature Adoption Likelihood per Income

If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Participants showed varying likelihoods of adopting different features based on their income brackets. Participants in the lower 40% income bracket showed a high likelihood of using Cafes, post services, and shared mobility, each rated at 4- 'somewhat likely'. Those in the middle 40% income bracket showed a particularly high likelihood of using post services, rated at 5, followed by a high likelihood of using the co-working spaces and refurbishing center with a score of 4- 'somewhat likely'. Participants in the top 20% income bracket showed a high likelihood (rated at 5) for ride-sharing. They were the least likely to use a hairdresser. Participants who preferred not to state their income where excluded from this analysis.

The results of the ANOVA tests for each adoption feature based on household income are presented below:

Feature	Correlation	P-value
Cafe	0.078	0.971
Co-working	0.457	0.715

Feature	Correlation	P-value
Gym	1.123	0.366
Hairdresser	0.396	0.757
Mobility Hub	1.970	0.155
Post Services	2.803	0.069
Refurbishing Center	0.791	0.514
Ride Sharing	4.711	0.013*
Shared Mobility	1.025	0.405

If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Key Observations

- **Ride Sharing** shows a statistically significant difference in adoption likelihood based on household income ($p < 0.05$).
- **Post Services** is close to the significance threshold, with a p-value of 0.069, suggesting a potential difference.
- Higher-income groups might be more likely to adopt ride sharing services compared to lower-income groups. Other features do not show statistically significant differences.

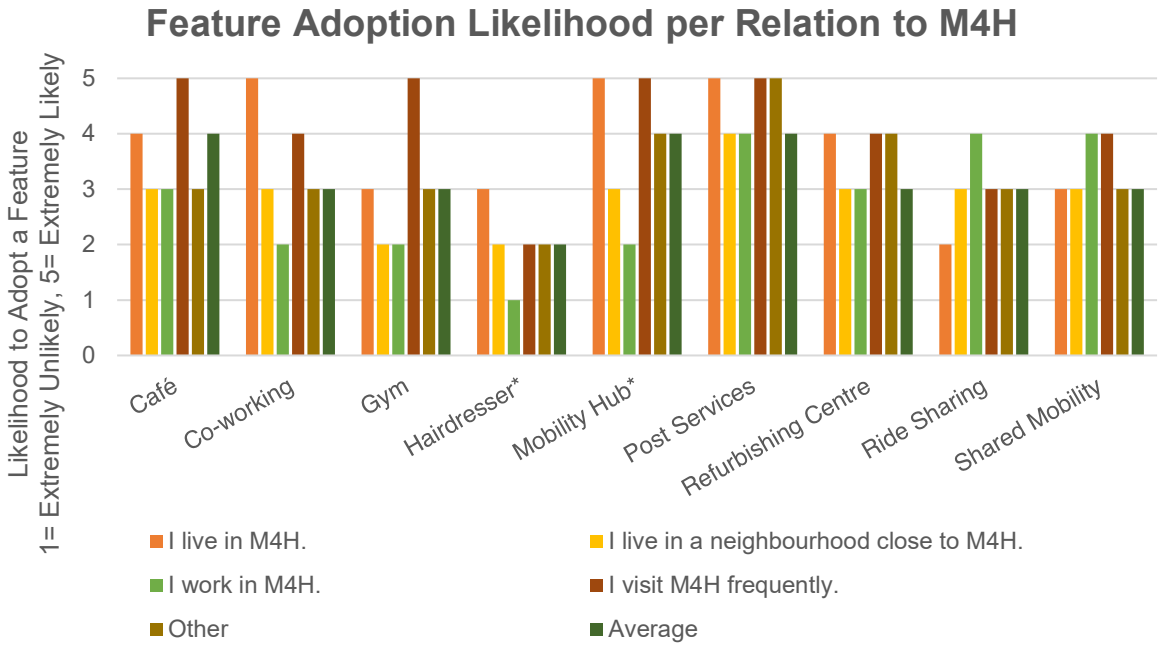


Figure 50 Feature Adoption Likelihood per Relation to M4H
If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Participants visiting M4H frequently are the most likely to use the cafe at the hub, followed by people living in M4H. Co-working spaces are most attractive to people living in M4H, followed by frequent visitors. People working in M4H are least likely to use co-working spaces. Frequent visitors to the area are also most likely to use the gym, followed by people living in M4H and others. People living in M4H are most likely to use the hairdresser, and people working there are extremely unlikely. People living in M4H or visiting it frequently are most likely to use the hub in general. People working in M4H are the least likely of all groups to adopt. All groups are likely to adopt postal services, while people living and visiting are among those scoring highest. The refurbishing center is similarly more attractive to residents and visitors than other groups. People working in M4H are most likely to share rides, while those living in M4H are the least likely to do so. Frequent visitors and people working in M4H are also more likely to use shared mobility in M4H's hub.

An interesting remark made by one of the participants during group interviews was, *"Because, yeah, let's say the site activities, I have it in Crooswijk, which is where I live. So, for me, I think shared mobility, in case parking would be forbidden on the street or whatever, that's relevant, I think. But just*

the coffee, the post service, the hairdresser, I can skip as well" (a person working in M4H).

The results of the ANOVA tests for each adoption feature based on the self-description related to M4H are presented below:

Feature	Correlation	P-value
Cafe	1.681	0.194
Co-working	1.361	0.292
Gym	2.191	0.102
Hairdresser	3.523	0.022*
Mobility Hub	3.238	0.030*
Post Services	0.857	0.547
Refurbishing Center	1.482	0.250
Ride Sharing	2.523	0.068
Shared Mobility	0.938	0.497

If the p-value is greater than 0.05, it indicates no statistically significant difference in means across the groups.
(*): The p-value is less than 0.05, indicating a statistically significant difference in means across the groups at the 5% significance level.
(**): The p-value is less than 0.01, indicating a highly statistically significant difference in means across the groups at the 1% significance level.

Key Observations

Mobility Hub and **Hairdresser** show statistically significant differences in adoption likelihood based on self-description related to M4H ($p < 0.05$).

- **Ride Sharing** is close to the significance threshold, with a p-value of 0.068, suggesting a potential difference that may be worth further exploration.
- For the **Mobility Hub**, highly likely adopters include individuals who live in M4H, visit M4H frequently, or have a combined role, such as living close and visiting frequently, or working and visiting frequently. On the other hand, less likely adopters are individuals who work in M4H without visiting frequently.
- For the **Hairdresser** services, highly likely adopters are individuals who live close to M4H and visit frequently. In contrast, less likely adopters are individuals who work in M4H or visit M4H frequently.

Key Insights

Participants' likelihood of adopting various features of the mobility hub varied across different demographic groups. First-generation migrants showed a high likelihood of using Cafes, co-working spaces, mobility hubs, postal services, refurbishing centers, and shared mobility, each rated at 4 (somewhat likely), with postal services at 5 (extremely likely). Second-generation migrants had similar preferences, with high likelihood ratings for Cafes, co-working spaces, post services, and refurbishing centers, each rated at 4 (somewhat likely). Participants with non-migrant background rated their likelihood of using Cafes, co-working spaces, gyms, post services, and refurbishing centers at 3 (neither unlikely nor likely). **Overall, Cafes, co-working spaces, postal services, and refurbishing centers are among the most likely features to be adopted**, particularly by first- and second-generation migrants. At the same time,

the **hairdresser feature is generally less likely to be used across all groups.**

Female participants showed a higher likelihood of adopting features such as cafes and postal services, each rated at 5 (extremely likely), and co-working spaces, the mobility hub, and refurbishing centers rated at 4 (somewhat likely). Male participants had a slightly lower likelihood of adopting these features, with the highest likelihood for postal services, rated at 4 (somewhat likely). Both genders rated gyms, ride-sharing, and shared mobility similarly, mostly at 3 (neither unlikely nor likely).

Participants reporting living as a couple showed a high likelihood of using mobility hubs, postal services, and shared mobility, with ratings of 4 or 5. Participants reporting living as couples with children showed a high likelihood of using postal services and refurbishing centers. Individuals living alone showed the highest interest in using the hairdresser among all groups, although the score was still 'neither likely nor unlikely'.

Participants in the lower 40% income bracket showed a high likelihood of using Cafes, postal services, and shared mobility, each rated at 4. Those in the middle 40% income bracket showed a particularly high likelihood of using postal services, rated at 5.

Participants visiting M4H frequently are the most likely to use the Cafe at the hub, followed by people living in M4H. Frequent visitors of the area are also most likely to use the gym, while people living in M4H are most likely out of all groups to use the hairdresser (with low still relatively low likelihood (3- neither likely nor unlikely)). Those working in M4H are the most likely to use shared mobility and ride-sharing (RQ1.3).

4.2.5 User Ideas for Additional Features or Services of the CMH

During the last step of the VR experience sessions, focus groups, study participants also discussed ideas for additional features and services that could improve or make the CMH's functionality better suited to their needs and habits, adding to their responses in the questionnaire. A person working in M4H summarized the features proposed by the participants as follows: *"Everything basically that makes your life easier and that you don't have to do when you get back home anymore."*

A frequently mentioned suggestion was the inclusion of a supermarket or meal services (15 mentions), indicating a strong desire for convenient access to daily necessities. One participant had an idea to include a ready-meal service that would allow travelers to buy packages with ingredients for a healthy dinner at home, *"a place where you can already pick up a whole package to make a meal, like HelloFresh or something like that"* (a frequent M4H visitor).

Public transport options were also commonly proposed (3 mentions) as, in general, participants mentioned they were disappointed to see a lack of public transport integration in the experienced scenario. *"I thought we also had some kind of train or metro involved in it, but I only saw how to use cars"* (resident of M4H).

Family-oriented services such as daycare (5), schools (3), and libraries (3) were popular suggestions, emphasizing the need for the hub to cater to families: *"Maybe integration of a daycare function in such a place or a playground because then you can travel and drop off your child in daycare or something like this. And then you're in this mobility hotspot where you can travel somewhere else easily"* (a resident of a neighborhood close to M4H).

Some participants also mentioned a medical care center (2) *"You could combine it with a health center, for instance. Then it could become a place where people could actually informally meet, see each other, or decide whether to use or not to use it"* (person working in M4H).

Additionally, bike and car repair shops were each mentioned, indicating the practical needs of residents who rely on these modes of transportation.

In addition to that, participants suggested the creation of public spaces (3) *"Use of public space around the building itself. So not just the building, but the use of green and open space could be integrated into the scenario"* (resident of a neighborhood close to M4H), community message boards (1), and places for workshops to enhance community engagement (1). These ideas usually came up during group conversations after the VR experience where participants exchanged ideas and personal experiences of the VR. Real-time availability tracking and facilities for groups were recommended to improve the efficiency and usability of shared resources.

Specific mobility-related features included services for vehicles suited for children and inclusive solutions for disabled individuals (1), pointing to the need for the hub to be accessible and user-friendly for all demographics. Art installations (1) and sports activities (1) were also suggested, indicating a vision for the hub as a vibrant community space offering recreational and cultural opportunities.

Figure 51 Additional Features Recommended by Participants- Word Cloud

Additionally, some ideas that were mentioned less frequently and emerged during group interviews when participants started discussing and exchanging ideas were, for example, creating the CMH to combine all functions of M4H and become not only a mobility hub but also a placemaking hub. One participant said, *"Maybe it should be a combination of all*

the elements that M4H has to offer, and that altogether forms the mobility hub. I think that would create some more value as well. If you want to make this kind of a special hub, this could be, for example, a placemaking idea" (a person working in M4H) (RQ1.4).

4.2.6 Qualitative User Feedback

During the focus groups, participants also discussed the potential functionality of CMH beyond its functions. For example, there were also mentions of providing job opportunities at the hub for communities nearby. For example, a resident of a neighborhood close to M4H mentioned, *"I think* [the opportunity lays] *somewhere in providing work. I mean, for example, car repair, people that work there would come from the neighborhood"* (a person working in M4H).

Moreover, when talking about how the hub could function, someone mentioned that if it was operated by an app, it should be a community app to keep them accountable for management and maintenance and, therefore, protect the communal aspects of it. For example, *"Keeping it community-based in the sense that the app is under the ownership of the community. I find that to be a very important and good idea. Because then you keep it accountable to the community"* (a person living in a neighborhood close to M4H).

A participant also expressed his passion for cars and said that while he understands the benefits of shared mobility, he would also like to see how his passion can be combined with the future scenario: "*I am passionate about cars and would simply like to own one and take care of it. At the same time, I can imagine the positive aspects of shared mobility and would like to understand how those two can be combined."*

Participants also expressed several concerns and criticisms regarding the proposed features and functionalities of the CMH. A major concern was digital dependency, with many participants highlighting issues related to the necessity of digital devices for accessing services. *"For example, I'm seriously considering ditching my smartphone because I find you're being tracked all the time. I find it dystopian. But if I don't have a smartphone, I won't be able to use the car"* (resident of a neighborhood close to M4H).

This concern underscores the potential exclusion of individuals who are less tech-savvy or do not own smartphones or do not have access to data, thereby emphasizing the need for non-digital access options.

It is also important to mention that participants indicated that such a facility should be focused on remaining communal and holding as few commercial functions as possible. On

the other hand, a few participants mentioned that they envision the hub as a center with many different "convenient services" that are easy to access and use.

For example, participants often expressed that despite the facility being a community facility, the way they experienced it resembled a commercial service: *"In the way that I experience it now is that it's being brought as a service rather than a facility, and because it's a service, it's also not a public service, but it's more of a privatized service, and I think that's a very bad idea"* (a person working in M4H).

A frequent M4H visitor:

"I really like the idea that we could seamlessly use the shared mobility going indoors to a public space indoors. But then, going through this, what I experienced was a shopping mall, or a garage in a shopping mall, or something in between. And then using the shared mobility wasted my time and also kind of, I mean, I call it like a walking wallet. So, please spend your money here and there. But I would like to use the quickest, seamless, reliable mode of transportation to go to my places. So, I think shared mobility is definitely a positive direction. But we should ask, how do we make it most convenient?"

The commercial nature of the hairdresser, in particular, was criticized most frequently. Many participants mentioned that such a service is very personal, and most of

them usually already have a trusted one: *"If you already live in a city in the neighborhood, you have your own hairdresser, which you trust" (a frequent M4H visitor).*

Including a gym was also debated, with concerns about its relevance and usage given the availability of similar facilities nearby. On the other hand, some said it would be nice to have a gym directly after arriving at the hub after work or using it on the way back home while departing from M4H.

Some participants were skeptical about the feasibility and practicality of features like hydrating soil using vehicles. They viewed these elements as overly complex or unnecessary, especially for the Dutch climate: *"But the watering of plants is a bit... Far-fetched. Extremely far-fetched. And it's solving a problem that shouldn't be there in the first place"* (a person living in M4H).

Additionally, the idea of using vehicle lighting at the hub was questioned, with some saying that an ordinary lighting system would do. Things like poor safety or insufficient light were mentioned if vehicles are not parked.

Ride-sharing was another feature that received mixed feedback. While some participants recognized its potential benefits, others were concerned about reliability, safety, and comfort based on past experiences. People working in M4H were more likely to use ride-sharing. They viewed it especially useful for commuting with colleagues. Others mentioned that they would, for example, feel uncomfortable riding together with strangers.

In summary, while participants provided valuable suggestions for enhancing the CMH, they also mentioned elements that they did not view as useful or suited to their daily routines. These include **reducing digital dependency, reevaluating the inclusion of certain commercial features, and maintaining high safety standards for shared mobility services.**

On the other hand, aspects that could increase the likelihood of using shared mobility and the CMH are diverse. According to the data presented in the chart, the top three factors are **convenience**, **good maintenance**, and **affordability**, each highly valued by the participants.

Convenience emerged as the most critical factor, with seven mentions. Participants emphasized the need for the CMH to integrate seamlessly with their daily routines, suggesting that the hub should capitalize on the *existing attractive elements of the district*. As one participant noted, *"look at what the district is already to offer to pick up the elements that are already attractive and create a hub from all the elements together"* (a person working in M4H). This indicates that the success of the CMH could depend on how well it aligns with the current lifestyle and habits of the community.

Good maintenance and **affordability** were highlighted as essential aspects, each mentioned six times. The emphasis on maintenance underscores the need for reliable, well-kept facilities that users can trust. Affordability is crucial as it directly impacts accessibility, especially for low-income residents. One participant suggested, *"Introduce free or discounted*

trial periods to allow people to experience the benefits of shared mobility without immediate financial commitment" (a person living in M4H), highlighting the importance of making services financially accessible to encourage initial use and build long-term habits.

Availability and **inclusivity**, with four mentions each, reflect the desire for the CMH to be accessible and welcoming to all community members. Availability relates to the flexible options and extended service hours suggested by participants, ensuring that the hub can cater to various schedules and needs. Inclusivity emphasizes the importance of designing the space in a manner that is attractive and tailored to the community, as one participant mentioned, *"I think designing the space in an attractive manner and tailored to the community would invite people to use it more"* (a person living in M4H).

Other factors such as **accessibility**, **ease of use**, **sustainability**, and **community building** were mentioned less frequently but still play significant roles. Accessibility ensures that all users can benefit from the hub. Ease of use relates to the simplicity and user-friendliness of the services provided. Sustainability reflects the growing concern for environmentally friendly solutions, while community building highlights the importance of creating a space that fosters social interactions and a sense of belonging.

In conclusion, the feedback from participants suggests that for the CMH to be successful, it must prioritize **convenience, good maintenance, and affordability**. Additionally, it should offer **flexible, inclusive, and accessible services** that cater to the **daily needs of the community**, while also promoting **sustainability and community engagement**. By addressing these factors, the CMH can increase its attractiveness and acceptance among potential users, ultimately contributing to a more sustainable and livable urban environment.

An important remark made by one of the participants was *"For me it would be interesting, for instance, because I always go by bike. But sometimes I also need to go places that are not even accessible by public transport and then I need to go by car. Which normally I don't want, because I want to be able to bike, it's also good for my health. So, being able to just get a car only for this one trip and then go back, that would mean a lot to me. And then, that's the kind of sharing that I love to do with people from my neighborhood."*

Key Insights

During focus groups, participants discussed the potential functionality of the Community Mobility Hub (CMH) beyond its core functions, emphasizing the importance of community-focused features. They suggested providing job opportunities at the hub for local residents, such as car repair services operated by neighborhood members. Participants also highlighted the need for a community-managed app for

CMH operations to ensure accountability and maintenance, reflecting the communal values of the area. Some participants expressed a passion for cars, seeking ways to integrate personal vehicle ownership with shared mobility benefits.

Concerns about digital dependency were discussed, with many participants worried about the necessity of digital devices for accessing services, potentially excluding those less tech-savvy or without smartphones. Participants stressed the importance of non-digital access options. The focus on maintaining the CMH as a communal facility rather than a commercial service was also emphasized. Participants criticized the commercial nature of certain proposed features, such as hairdressers and gyms, arguing that these services felt privatized and were not necessarily aligned with community needs.

Additionally, participants questioned the practicality of certain features, like using vehicles for hydrating soil and vehicle lighting at the hub, suggesting simpler alternatives. Ride-sharing received mixed feedback; some valued it for commuting, while others were concerned about safety and comfort. The discussions underscored the need to balance convenience, community orientation, and practical functionality in the CMH design.

Participants identified key factors for increasing the likelihood of using shared mobility and the CMH, including convenience, good maintenance, affordability, availability, and inclusivity. They emphasized the need for the CMH to integrate seamlessly with daily routines, ensure reliable and well-maintained facilities, and offer financially accessible services. Designing the space to be attractive and tailored to the community's needs was also highlighted as essential.

4.2.7 The Role VR Experience in the Study

In general, more than half (13) of the participants indicated that after experiencing the VR scenario, they understand the concept of community mobility hubs better, with one participant explicitly stating, *"I think the immersive experience, or showing people how it would look like, is a positive feature of this research. I mean, it raises a lot of questions that maybe it was harder to realize without seeing it"* (frequent visitor of the M4H area). Within that group, some (4) indicated that they would be more likely to use the facility and shared vehicles. One participant remarked, *"I don't think they changed much* [perceptions about shared mobility], *but I now understand the presented concept better. I could actually consider using such a facility"* (resident of a neighborhood close to M4H). Another participant expressed a similar sentiment: *"I understand better what shared mobility is and how it can be used and what the possibilities are"* (resident of a neighborhood close to M4H) (RQ1.5).

4.2.8 Part 1 Insights

The participant demographics were varied, with balanced age distribution and diverse household compositions, income levels, and connections to the M4H area. Participants included seven aged 18-26, nine aged 27-39, and six aged 40-54, along with seven females and fifteen males. The participant group was composed of six first-generation migrants, two second-generation migrants, thirteen with no migrant background, and one who preferred not to disclose this information. The diversity of household compositions included couples, couples with children, individuals living alone, those living with housemates, and other arrangements. In terms of income, five participants were in the lower 40% income bracket, thirteen in the middle 40% bracket, and three in the top 20% bracket, with one participant not disclosing their income. Participants' connections to the M4H area varied, including residents (three in M4H, nine close to M4H), workers (four), frequent visitors (two), and those with other types of connections (four).

Participants reported diverse travel behaviors, with walking, cycling, cars, and public transport being the most common modes of transportation. Bicycles were frequently used, with seven participants cycling daily, while car usage was less consistent. Public transport saw moderate usage, with daily use by seven participants. Shared mobility options were the least used, highlighting a potential area for improvement. Walking was the most consistent mode, with twenty participants walking daily. The purpose of trips varied, including visiting others, shopping, commuting to work, and recreational activities. Trip durations ranged from short shopping trips (5-10 minutes) to longer work commutes (10-40 minutes).

Participants' experiences with shared mobility varied, with shared bikes being the most commonly used, followed by shared scooters, cars, and cargo bikes. Key valued features of shared mobility included convenience, ease of use, availability, reliability, and travel time. However, barriers such as complexity, inconvenience, lack of comfort, poor availability, and poor accessibility were noted, particularly by those who had not used shared mobility options before. Trust issues regarding the condition of shared vehicles were also mentioned.

The post-VR reflection phase revealed participants' perceptions of the proposed mobility solutions. The majority found the concept somewhat attractive or neither attractive nor unattractive, indicating room for improvement. Key concerns included affordability, reliability, and availability, with issues such as safety, accessibility, comfort, and ease of use also highlighted. Participants emphasized the importance of convenient, affordable, and well-maintained services. Preferred amenities included cafes, postal services, and refurbishing centers, while hairdressers were the least favored.

The research identified distinct user groups based on migrant background, gender, household composition, income, and their relation to M4H. First-generation migrants favored cafes, co-working spaces, mobility hubs, and postal services. Females showed a higher likelihood of adopting features such as cafes and post services, while males had a slightly lower likelihood. Couples, particularly those with children, favored postal services and refurbishing centers, while individuals living alone showed among all groups the highest interest in hairdressers (yet still generally low). Lower-income participants preferred

services such as shared mobility and cafes.

Participants suggested additional features for the CMH, including supermarkets, meal services, public transport options, family-oriented services like daycare, schools, and libraries, medical care centers, and repair shops. The creation of public spaces and community message boards was also recommended. Ideas for integrating various functions of M4H to create a placemaking hub were discussed, emphasizing the need for a community-focused approach.

Participants discussed the potential functionality of CMH, highlighting the need for community job opportunities, a community-managed app for accountability, and balancing personal vehicle ownership with shared mobility benefits. Concerns about digital dependency and the importance of non-digital access options were emphasized. Participants preferred maintaining the CMH as a communal facility with minimal commercial functions.

The use of VR technology helped participants better understand the concept of community mobility hubs. More than half indicated an improved understanding after the VR experience, with some expressing a higher likelihood of using the facility and shared vehicles. The immersive experience provided valuable feedback, highlighting the potential and challenges of the proposed mobility solutions.

5

5 Discussion and Recommendation

The research conducted on the M4H CMH brings together multiple dimensions of urban planning, mobility trends, and community engagement. The VR experience sessions provided immersive insights into the future mobility solutions proposed for the area. These sessions were crucial for gathering feedback from diverse user groups, which included varying demographics such as age, gender, migrant background, household composition, income level, and relationship to M4H.

This research aimed to investigate how the proposed CMH in M4H can be adapted to meet the diverse needs of its potential users. The primary objectives include providing insights into the demographic and socio-economic profiles of the communities around M4H (also considered potential future users) (O1), understanding the primary mobility patterns of communities around M4H (also considered potential future users) (O2), gathering user feedback on the current plans for the CMH (O3), developing feature recommendations to meet diverse user needs (O4), and investigating the effectiveness of innovative technologies for citizen engagement (O5). The following sections focus on describing the implications of this research (section 5.1) but also its strengths and limitations (section 5.2). Section 5.3 provides future research directions.

5.1 Research Implications

This section focuses on answering the research questions. Section 5.1.1 will answer RQ1.1, section 5.1.2 will answer RQ1.2, section 5.1.3 will answer RQ1.3, section 5.1.4 will answer RQ1.4. Finally section 5.1.7 provides the recommendations for the CMH in M4H (main RQ).

5.1.1 Demographic and Socioeconomic Profiles of Potential M4H Users

The neighborhood analysis revealed a diverse socio-demographic landscape in the areas surrounding M4H. The population includes a large share of young individuals, particularly those aged 27-39 years, as well as families with children and elderly individuals. Household compositions are varied, encompassing single-person households, couples with and without children, and single-parent families. The socioeconomic profile predominantly features low to middle-income households, with a significant presence of first- and second-generation migrants from various cultural backgrounds, including Dutch, European, Moroccan, and Turkish origins (section 3.2.1).

Implications

The diverse demographic and socioeconomic profiles suggest that the CMH needs to offer a wide range of services and features to cater to diverse needs. Including affordable and accessible services (following 4A's Inclusive Transport Framework) is crucial to ensure that low-income households can benefit from the hub. Understanding the multicultural aspect of the community can guide the development of culturally sensitive services and strategies (Schmitt, 1952).

5.1.2 Primary Mobility Patterns of Potential M4H Users

The analysis of mobility patterns from the ODiN study (section 3.2.2) and VR experience sessions (section 4.2.2) revealed that residents around M4H engage in various travel purposes,

including shopping, commuting to work, visiting/staying over, and recreational activities such as touring and hiking. Walking, cycling, passenger cars, and public transport emerged as the most frequently used modes of transportation, underscoring the need for a multimodal transport system within the CMH to enhance user convenience and accessibility.

Distinct travel behaviors were observed based on household compositions and income levels. Households with children prioritized drop-off and pick-up-related trips, while households with couples, children, and additional occupants emphasized touring and hiking trips. Single-parent households exhibited the highest share of education trips compared to other household types. Lower and mid-range-income households tended to engage in longer-distance trips, particularly for work purposes.

Implications

Households with children may benefit from larger shared vehicles or secure bike trailers, while single-parent households require safe and accessible routes for school trips. The preference for different transport modes, such as walking, cycling, passenger cars, and public transport, highlights the necessity for seamless integration of these modes within multimodal transport hubs. Additionally, the tendency of lower and mid-range-income households to engage in longer-distance trips for work emphasizes the need for affordable and efficient long-distance travel options. These variations underscore the need for mobility solutions that are tailored to the specific needs of different household types and income groups (Schmitt, 1952).

5.1.3 User Receptivity Towards Plans for the CMH in M4H

The VR experience sessions provided valuable feedback on the proposed mobility solutions, offering insights into user perceptions and preferences (section 4.2.3). Participants generally found the concept of community mobility hubs attractive, preferring amenities such as cafes, postal services, and refurbishing centers. However, significant concerns about affordability, reliability, and service availability were raised, indicating these aspects need prioritization to ensure the acceptability and success of the CMH.

Perceptions of the current plans for the CMH varied across different user groups (section 4.2.4). Distinct user groups were identified based on migrant background, gender, household composition, income, and their relation to M4H. This segmentation was crucial for assessing the potential perceptions and needs of the development's target users.

First-generation migrants showed a high likelihood of using cafes, co-working spaces, mobility hubs, postal services, refurbishing centers, and shared mobility, particularly valuing postal services. Second-generation migrants had similar preferences. Participants with no migrant background had moderate likelihood ratings for most features. However, statistically, migrants (both first and second generation) are generally more likely to adopt hairdressing services than those with no migrant background, with second-generation migrants showing the highest likelihood.

Female participants were more likely to adopt cafes and postal services, with higher likelihood ratings for co-

working spaces, the mobility hub, and refurbishing centers compared to males. These results are statistically significant. Both genders rated gyms, ride-sharing, and shared mobility similarly.

Household composition also influenced preferences. Couples and couples with children were most likely to use mobility hubs, postal services, and refurbishing centers, while individuals living alone were out of all most interested in hairdressers (yet still not highly). Those living with housemates were most likely to use cafes and gyms. There were no statistically significant differences in the adoption likelihood per household composition.

Income levels further differentiated preferences. Lower-income participants preferred cafes, postal services, and shared mobility. Those in the middle-income bracket showed a particularly high likelihood of using postal services and co-working spaces, while participants in the top-income bracket were most likely to use ride-sharing services. Ride sharing shows a statistically significant difference in adoption likelihood based on household income indicating that higher-income groups might be more likely to adopt ride sharing services compared to lower-income groups.

Participants who frequently visit M4H are the most likely to use amenities like the cafe, gym, and postal services, followed by residents of M4H. Co-working spaces and hairdressers are also popular among residents, while those working in M4H are the least likely to use these features. The refurbishing center is most attractive to both residents and frequent visitors. Ride-sharing and shared mobility options are more likely to be used by frequent visitors and workers in M4H, with residents being the least likely to share rides. ANOVA analysis revealed significant differences in adoption likelihood for the Mobility Hub and Hairdresser services based on self-description related to M4H, with those living in or frequently visiting M4H being the most likely adopters. Ride-sharing showed a potential difference.

Implications

These findings highlight the importance of targeting the user groups that show a generally higher perceived likelihood of using the presented M4H features (e.g., females or people of migrant backgrounds). According to the Diffusion of Innovations theory (Rogers, 1971) this approach can speed up the general adaptation process and assist the mobility transition.

5.1.4 Additional CMH Features Recommended by Users

Participants suggested several additional features and services for the CMH (section 4.2.5), including supermarkets, meal services, public transport options, family-oriented services like daycare, schools, and libraries, medical care centers, and repair shops. These recommendations reflect the community's desire for a comprehensive mobility hub that caters to various daily needs and enhances the overall quality of life. Public spaces and community message boards were also recommended to foster community engagement and interaction.

Additionally, the research highlighted the importance of community ownership and management of the CMH to ensure accountability and relevance to local needs. Participants preferred a community-managed app for CMH operations, reflecting the

communal values of the area. However, concerns about digital dependency were raised, emphasizing the need for non-digital access options to avoid excluding less tech-savvy individuals who do not own smartphones section 4.2.6).

Implications

These suggestions align with the theoretical insights on the importance of providing comprehensive and flexible urban spaces that cater to multiple functions. The recommendations emphasize the need for the CMH to offer convenient access to daily necessities, promote social interactions, and enhance community engagement. Furthermore, they align with the design principles for Community Mobility Hubs listed in the plans for M4H (APPM Management Consultants et al., 2022).

5.1.5 Effectiveness of Innovative Technologies for Citizen Engagement

The use of VR technology in this research proved effective in engaging participants and gathering detailed feedback (section 4.2.7). More than half of the participants indicated an improved understanding of the community mobility hub concept after experiencing the VR scenario. The immersive experience provided a tangible preview of the proposed solutions, helping participants visualize and evaluate the potential impact on their daily lives. This innovative approach to citizen engagement aligns with the theoretical framework's emphasis on participatory planning and community involvement in urban development processes.

Implications

The positive reception of VR as a tool for citizen engagement underscores its potential for future urban planning initiatives. It offers a tangible and interactive method for presenting plans and gathering user feedback, ensuring that the community's voices are heard and considered in the planning process. The findings of the research confirmed existing knowledge stating that VR can be a platform where community members can be better engaged and virtually explore proposed developments, understand the concepts better and provide real-time feedback (Azofeifa et al., 2022).

5.1.6 Findings Integration

This research demonstrates the importance of combining quantitative data from demographic and mobility pattern analyses with qualitative insights from immersive VR experiences. The neighborhood analysis provided a foundational understanding of the community's demographic and socioeconomic characteristics, while the VR sessions added a layer of nuanced feedback on user preferences and perceptions.

While the participant sample may not fully represent the entire population around M4H, it covers a broad spectrum of demographic characteristics and provides valuable insights into the needs and preferences of the majority of potential users. This diversity is crucial for developing inclusive and equitable mobility solutions.

Implications

Integrating these methods offers a comprehensive approach to urban planning, ensuring that recommendations for the CMH are grounded in both empirical data and community-driven insights. This combined approach helps create more inclusive and effective mobility solutions, reflecting the diverse needs and preferences of potential users in

the M4H area. The additional layer of citizen engagement through VR provided valuable insights that would not have been captured through traditional quantitative methods alone and included diverse voices, promoting social fairness and cohesion (Gagan Deep, 2023b).

5.1.7 Adapting the CMH to Meet Diverse User Needs

The study contributes to the theoretical understanding of mobility transition and inclusive urban planning by providing evidence on the diverse mobility needs and preferences of different user groups. The findings support the theories on community engagement in creating sustainable and equitable urban spaces.

The findings highlight the need for a tailored approach in the design and implementation of the CMH for the Municipality of Rotterdam, Deloitte, and MINI. This includes providing a range of services that cater to the community's diverse needs, integrating advanced technologies like VR to enhance planning and engagement, and ensuring that mobility solutions are affordable, reliable, and accessible to all demographic groups.

The recommended strategy for adapting the Community Mobility Hub to meet diverse user needs includes (RQ):

1. **Include Solutions for Diverse Demographics Focusing on Families, People of Migrant Backgrounds, and Low Income:** Create accessible, affordable, acceptable, and available transport solutions that cater to the specific needs of these groups, ensuring inclusivity and equity in mobility options.

2. **Incorporate Practical Features:** Design the CMH to accommodate a variety of activities, including shopping, commuting, and recreational purposes, ensuring it meets the needs of residents with different travel behaviors.

3. **Resolve Worries About Affordability, Availability, and Reliability:** Maintain ongoing dialogue with the communities to address their concerns and ensure the CMH remains responsive to their needs.

4. **Focus on Convenience, Maintenance, and Pricing Schemes:** Develop the CMH with a particular emphasis on features such as convenience, good maintenance, and various pricing schemes to cater to different communities. These aspects are likely to attract new users.

5. **Affordable Transportation Solutions:** Offer subsidized or affordable transport options, including public transport connections and affordable shared mobility services, to cater to lower and mid-range income households.

6. **Target User Groups Showing Most Interest in the Proposed Solutions:** Focus on user groups with a generally higher perceived likelihood of using the presented M4H features (e.g., females or people of migrant backgrounds). This approach can speed up the general adaptation process and assist the mobility transition.

7. **Include Comprehensive Services and Family- Friendly Amenities:** Integrate services such as cafes, post offices, supermarkets, and meal services within the CMH, and ensure they are community-managed. Incorporate green spaces and public areas to create an environment encouraging community interaction and informal meetings. Provide amenities like larger car-share vehicles and child-friendly spaces to support families with children. Integrate family services such as daycares, schools, and libraries to support families and enhance the convenience of the CMH.

8. **Ensure Community Ownership and Accountability:** Encourage community ownership and management of the CMH to build trust, foster accountability, and ensure the

hub reflects local needs and preferences.

9. **Resolve Digital Dependency Concerns:** Provide digital platforms and non-digital access points for CMH services to ensure inclusivity for all users, including those less tech-savvy.

10. **Keep Engaging the Community in Innovative Ways:** Maintain a continuous dialogue with the community, providing space for knowledge and information exchange and co-creation to adapt the CMH to evolving needs and preferences.

5.2 Strengths and Limitations

This study has several limitations that must be acknowledged. One limitation is the limited representation of female participants, which could skew the findings. In addition, the self-reported nature of some data might introduce biases, as participants' responses could be influenced by their subjective interpretations and current mood.

Furthermore, although effective in providing immersive experiences, the VR simulation may not completely replicate real-world scenarios, potentially affecting participants' perceptions and feedback. The VR model developed by Deloitte featured a fixed scenario with a fixed storyline, limiting the flexibility and realism of the experience. While the VR simulation provided a valuable preview of the proposed mobility solutions, its fixed nature may not fully capture the community's dynamic and varied real-world interactions.

Another limitation is the influence of group dynamics in the focus group sessions. Participants may have influenced each other's opinions and responses, potentially leading to conformity bias. Individual responses were captured through questionnaires before group discussions to mitigate this.

Additionally, there might be a bias stemming from the participants' interest in VR technology. Individuals particularly interested in VR may also have a positive attitude toward technology in general, including autonomous cars and other advanced mobility solutions. This technological optimism could influence their feedback, making them more favorable towards the proposed solutions than the general population might be.

Finally, the study involved potential future residents of M4H rather than current residents, which could make it difficult for participants to estimate their future needs and wants accurately.

Despite these limitations, the study has several strengths. One key strength is its innovative use of VR to simulate future mobility scenarios, providing participants with a tangible experience of the proposed solutions. This approach enhances the realism of the feedback and engages participants in a more interactive and immersive manner. Additionally, the focus on a diverse participant pool, including different migrant backgrounds, genders, and household compositions, enriches the understanding of varied mobility needs.

Including a diverse participant pool ensures that a wide range of perspectives and preferences are considered, providing a more

comprehensive understanding of the community's mobility needs. This diversity is particularly important in the context of M4H, which is characterized by its culturally diverse population and varied household compositions.

In conclusion, while the study's limitations, such as potential biases, the fixed nature of the VR simulation, and the possible bias towards technology, must be considered when interpreting the results, the innovative use of VR and the inclusion of a diverse participant pool are significant strengths. These elements contribute to a richer, more nuanced understanding of future mobility needs and preferences, which can inform the development of more inclusive and effective mobility solutions for the M4H community.

5.3 Future Research Directions

Gemeente Rotterdam

1. **Conduct Longitudinal Studies:**

Implement longitudinal studies to track changes in mobility patterns and preferences over time, providing deeper insights into evolving mobility needs and supporting more informed urban planning decisions.

2. **Enhance Community Engagement:**

Increase efforts to engage current M4H residents and surrounding neighborhoods through workshops, town hall meetings, and surveys to gather direct input on mobility solutions and other urban development plans.

3. **Diversify Participant Demographics:**

Ensure a balanced representation of gender, age, and other demographics in future studies to capture a comprehensive view of the community's diverse mobility needs and preferences.

4. **Integrate Public Transport in VR Simulations:**

Develop VR simulations incorporating public transport options to provide a more holistic experience that accurately reflects the actual mobility ecosystem.

Deloitte

1. **Improve VR Simulation Quality:**

Invest in enhancing the quality and flexibility of VR simulations. This will allow for more dynamic and interactive scenarios that adapt to participants' inputs and reflect a wider range of real-world situations.

2. **Expand VR Research Applications:**

Explore VR's use in other urban planning areas beyond mobility, such as housing, public spaces, and environmental sustainability, to provide valuable insights and foster a comprehensive urban development approach.

3. **Address Technological Optimism Bias:**

To balance potential biases from those particularly interested in VR and technology, participants with varying degrees of technological familiarity should be included, obtaining a more representative view of the general population's attitudes.

MINI

1. **Focus on User- Centered Design:**

Prioritize user-centered design principles in developing mobility solutions, gathering detailed feedback from potential users to ensure the solutions meet actual needs and preferences.

2. **Pilot Test Shared Mobility Solutions:**

Conduct pilot tests of shared mobility solutions in diverse neighborhoods, understanding practical challenges and opportunities in implementing these solutions across different socio-economic contexts.

3. **Explore Additional Mobility Features:**

Investigate the feasibility and benefits of additional features suggested by participants, such as meal services, public transport options, family-oriented services, and repair shops, enhancing the attractiveness and utility of mobility hubs.

General Recommendations

1. **Collaborative Research Initiatives:**

Foster collaboration between Gemeente Rotterdam, Deloitte, MINI, and other stakeholders to conduct joint research initiatives, leveraging strengths and resources for comprehensive and impactful results. During the study, several stakeholders expressed interest in the topic and willingness to stay informed and contribute to the developments.

2. **Utilize Mixed- Methods Approaches:**

Combine qualitative and quantitative research methods for a holistic understanding of mobility needs and preferences, providing richer insights and supporting robust conclusions.

3. **Invest in Data Infrastructure:**

Develop robust data infrastructure to support ongoing research and monitoring, enhancing geospatial data collection, improving data integration capabilities, and ensuring data accessibility for all stakeholders.

6

6 Conclusion

This research explored the mobility needs and preferences of potential users in the Merwe-Vierhavens (M4H) area, focusing on developing actionable recommendations for a Community Mobility Hub (CMH). Utilizing desk research, virtual reality (VR) simulations, questionnaires, and focus groups, the study provided comprehensive insights into the diverse requirements and perceptions of different user groups.

Initially, the research aimed to understand the demographic and socio-economic profiles of the communities around M4H. The neighborhood analysis revealed a diverse population, predominantly young individuals aged 27-39, families with children, and single-person households. A significant portion of the residents had migrant backgrounds, contributing to the area's cultural diversity. The socio-economic analysis indicated that these neighborhoods are generally low-income, with households predominantly falling into the lower and middle-income brackets. This diverse demographic and socioeconomic profile underscores the need for the CMH to offer a wide range of services and features to cater to different needs, particularly emphasizing affordable, accessible, acceptable, and available transport solutions.

In the next part, the study examined the primary mobility patterns of these communities. The analysis of data from the Onderweg in Nederland (ODiN) study showed that residents in the neighborhoods around M4H exhibit varied travel behaviors. Common trip purposes included shopping, commuting to work, visiting/staying over, and recreational activities. Walking, cycling, cars, and public transport were the most frequently used modes of transportation. These findings highlight the necessity for a multimodal transport approach within the CMH. The study also identified distinct travel behaviors based on household compositions and income levels. For instance, households with children showed higher frequencies of picking up/dropping off people, while lower and mid-range-income households tended to engage in longer-distance trips for work purposes.

The VR experience sessions formed the core of the study, providing participants with an immersive preview of the proposed mobility solutions. These sessions were instrumental in gathering detailed feedback, allowing participants to engage interactively with the proposed CMH features. The VR simulations indicated a strong preference for amenities such as cafes, co-working spaces, postal services, and refurbishing centers. These features were particularly favored by first- and second-generation migrants, emphasizing the need for inclusive and culturally sensitive planning. Participants also expressed significant concerns regarding affordability, reliability, and availability of mobility solutions, suggesting that prioritizing these aspects is crucial for the acceptability and effectiveness of the CMH.

User receptivity towards the current plans for the CMH varied across different demographic groups. First-generation migrants were likely to use cafes, co-working spaces, post services, and refurbishing centers. Female participants were more likely to adopt features such as cafes and postal services, while male participants had a slightly lower likelihood. The preferences among different household compositions highlighted the importance of considering

demographic diversity in the CMH design. For instance, couples with children were more likely to use postal services and refurbishing centers.

Participants provided several recommendations to enhance the CMH's functionality. Common suggestions included supermarkets, meal services, public transport options, and family-oriented services like daycare, schools, and libraries. The inclusion of medical care centers, bike and car repair shops, and public spaces was also recommended. These suggestions align with the theoretical insights on providing comprehensive, flexible urban spaces catering to multiple functions.

The application of VR technology proved highly effective in engaging participants and gaining detailed feedback. However, the study acknowledged several limitations, such as potential biases in self-reported data and the fixed nature of the VR scenario, which may not fully capture the dynamic and varied real-world interactions. Despite these constraints, the research offers a comprehensive overview of the mobility needs in M4H and presents actionable recommendations for developing a community mobility hub.

Future research should aim to expand the sample size to ensure a more representative demographic and conduct longitudinal studies to capture evolving mobility preferences over time. Incorporating real-world testing alongside VR simulations could further enhance the validity and applicability of the findings. Addressing these areas in future studies will build on the foundation laid by this research, contributing to the creation of more inclusive and sustainable urban mobility solutions.

For Gemeente Rotterdam, the findings highlight the need for a tailored approach in the design and implementation of the CMH. This includes providing a range of services that cater to the community's diverse needs, integrating advanced technologies like VR to enhance planning and engagement, and ensuring that mobility solutions are affordable, reliable, and accessible to all demographic groups. Deloitte should aim to improve the quality and flexibility of VR simulations, allowing for more dynamic and interactive scenarios that adapt to participants' inputs and reflect a wider range of real-world situations. MINI should focus on user-centered design principles in developing mobility solutions, gathering detailed feedback from potential users to ensure the solutions meet actual needs and preferences.

Overall, this study underscores the importance of understanding and integrating the diverse mobility needs of community members in planning and developing urban mobility hubs and the possibilities VR offers to gain those insights. The insights gained can guide policymakers, urban planners, and stakeholders in creating more inclusive, accessible, and user-centered mobility solutions in M4H and beyond. The innovative use of VR technology and the inclusive approach of engaging a diverse participant pool have provided a richer, more nuanced understanding of future mobility needs, significantly informing the development of effective and sustainable urban mobility solutions.

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APPENDICES

Appendices

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APPENDIX A

M4H Development Strategy

Overview of the Ruimtelijke Raamwerk Merwe-Vierhavens and Mobiliteitsstrategie Merwe-Vierhavens Documents

Marta Nosowicz

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1. Introduction

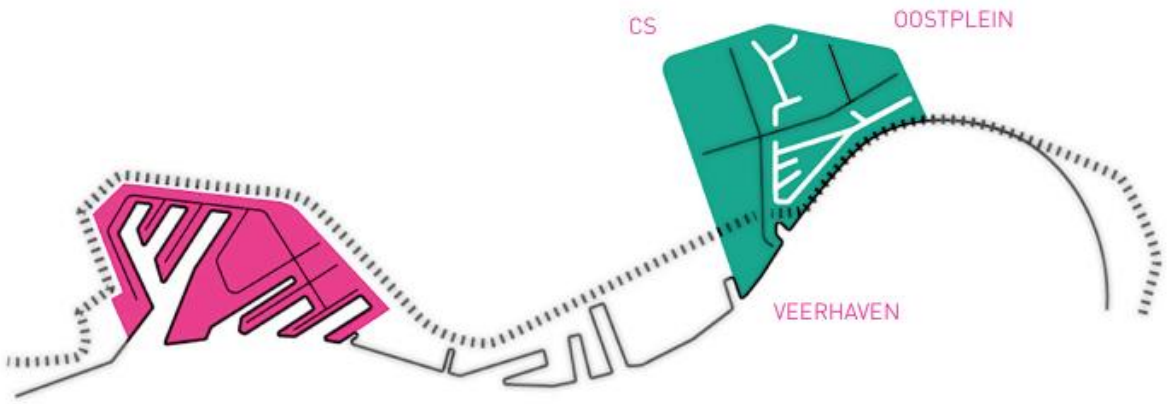


Figure 1 M4H Location and Size in Comparison to the City Centre of Rotterdam (Delva, 2019)

Merwe-Vierhavens (M4H) is a large area comparable in size to the inner city of Rotterdam (Figure 1). The municipality of Rotterdam and the Rotterdam Port Authority want to develop M4H into an innovative living-work environment, optimally equipped for innovative manufacturing industry and with a mix of functions such as culture, catering, sports, and education. Some of the key elements of the strategy are *well-connected shared modes of transport, prioritizing sustainable mobility such as cycling, public space that encourages being active and at the same time one where visitors can find peace and places to relax* (Rotterdam Makers District, 2019).

Figure 2 M4H Development Plan- Vision 2050 (Delva, 2019)

This document is an overview of the publicly available development plans, namely *the Ruimtelijke Raamwerk Merwe-Vierhavens* created by DELVA Landscape Architecture and Urbanism *and Mobiliteitsstrategie Merwe-Vierhavens* created by APPM Management

Consultants, Stadkwadraat, Goudappel Coffeng and Verkeersonderneming. Both assignments were commissioned by Rotterdam Makers District.

The goal of this paper is to summarize the key points of the development plans for M4H. The following chapters will first introduce the general vision (Chapter 2) and next focus on the mobility strategy for the area (Chapter 3). The paper will be concluded in Chapter 4.

2. M4H Development Principles

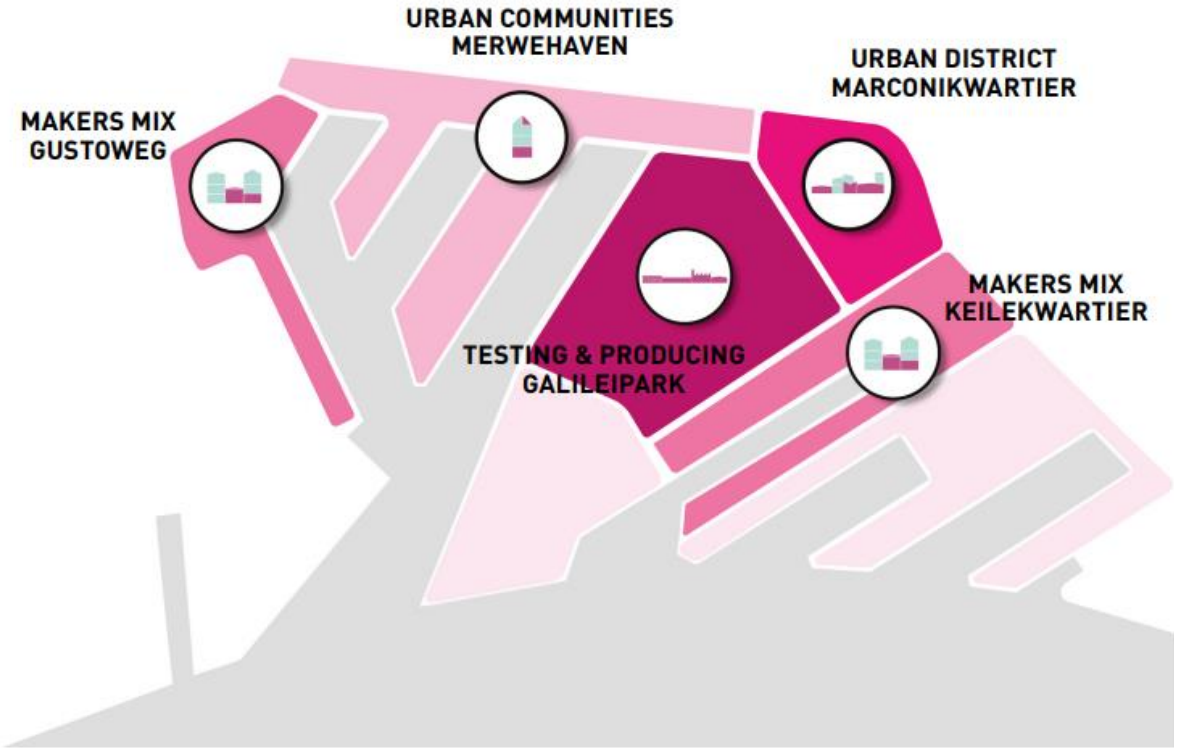


Figure 3 Main Programming Structure M4H (Delva, 2019)

The programming for M4H aims to create a vibrant and mixed environment which facilitates working, experimenting and living (Figure 3). There will be room for schools, healthcare, parks and spaces for entrepreneurs (Rotterdam Makers District, 2019).

The ambition is to build 3.400- 5.100 new houses, new workspace and introduce new facilities by 2035. The aim is to make 60% of M4H affordable (rent up to 1,075 euros and purchase up to 355,000 euros – price level 2023). The emphasis is on apartments for empty nesters, couples without children and young professionals living on their own (Wonen in Rotterdam, 2023).

According to the Ruimtelijk Raamwerk-Merwe-Vierhavens (2019) document created by DELVA Landscape Architecture and Urbanism the development is guided by 8 principles where circularity based on collectivity is the overarching theme:

1. M4H keeps space for different types of entrepreneurs and creatives.
2. M4H prioritizes collectivity over private ownership of goods.
3. M4H provides free zones for experimenting and learning.
4. M4H produces and uses sustainable energy.
5. M4H implements circularity.
6. M4H makes it possible to choose for sustainable mobility.
7. M4H functions as one climate-resilient system.
8. M4H uses the current industrial capacity of the area.

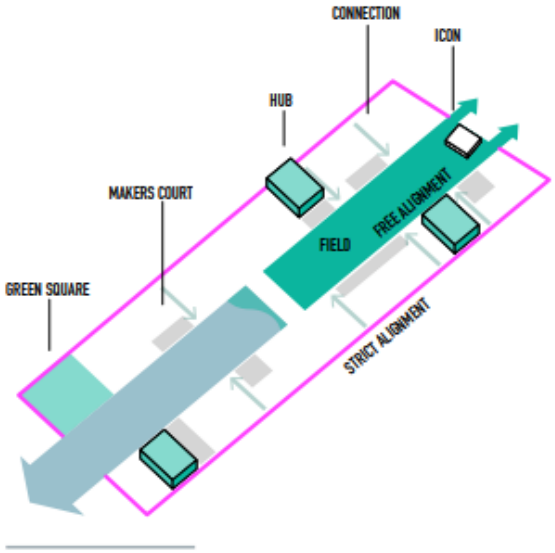


Figure 4 Development Concept M4H(Delva, 2019)

2.1 Public Space

GREENERY

M4H will transition from a stony waterfront to a green area. The goal is to create a range of diverse greenery typologies (Figure 5). Greenery will generate quality of life, reduce heat stress, and introduce biodiversity. Buildings, streets, squares, and parks, along with the water, will form an integral whole to create an ecosystem (Rotterdam Makers District, 2019).

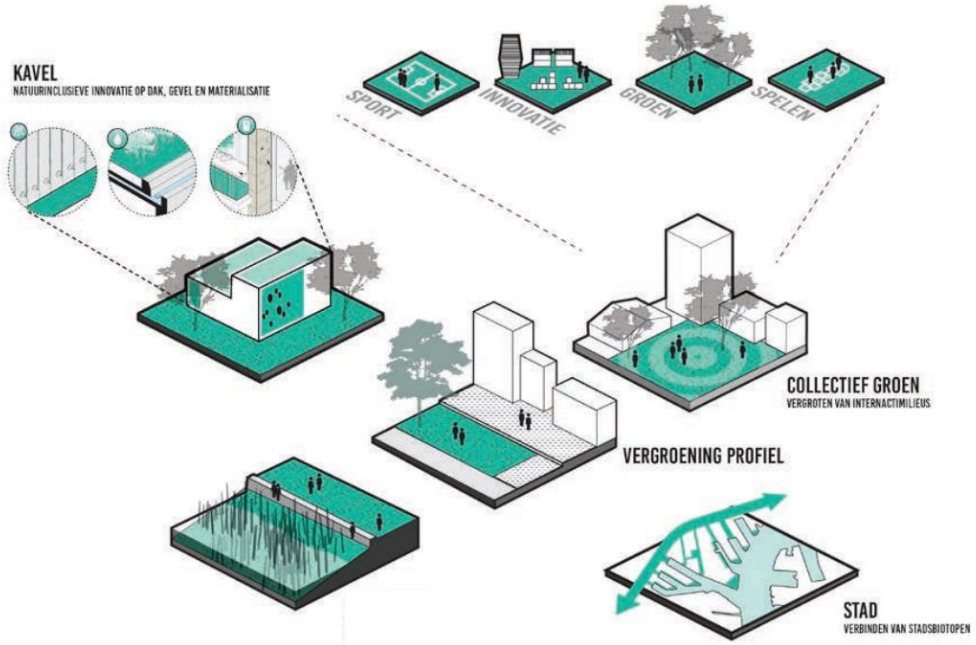


Figure 5 Implementing Greenery in M4H at Different Levels (Delva, 2019)

OPEN SPACE

There will be new open public space introduced in the area. New squares will be suitable for events and manifestations. The functions in the plinths will determine the activities of the squares (Rotterdam Makers District, 2019)

STREETS

The main streets for M4H will be the Makersstraat (Keileweg and Galileistraat) and the Havenallee (Marconistraat and Benjamin Franklinweg) (Figure 6). Additionally, there will be a series of Havenstraten: the streets that provide access to the individual harbors from the dike route. Each Havenstraat will have its own profile (Figure 7), depending on the situation, but they all belong to the same family (Rotterdam Makers District, 2019).

The Makersstraat will connect the Keileweg and the Galileistraat and form the main access route of M4H. Many users will be accommodated in the profile of the street, from trucks to pedestrians and from e-bikes to delivery vans. Three so-called flex zones will be included in the profile. These zones will have diverse uses: loading and unloading for delivery vans, terraces, bike racks, lighting, underground containers, greenery, and water storage (Rotterdam Makers District, 2019).

The Havenallee will have to handle less car traffic than the Makersstraat. Therefore, the Havenallee will have a narrower profile for the roadway with a wide bike lane on both sides. This

will provide space for cyclists, e-bikes, scooters, etc., and requires cars to adapt. Together with the wide sidewalks and the flex zones with greenery and street furniture, the Havenallee will be a pleasant route for slow traffic and for staying (Rotterdam Makers District, 2019).

In all cases, the profile facilitates the pleasant use of amenities such as restaurants, education, childcare, shops, company restaurants, and workplaces for freelancers (Rotterdam Makers District, 2019).

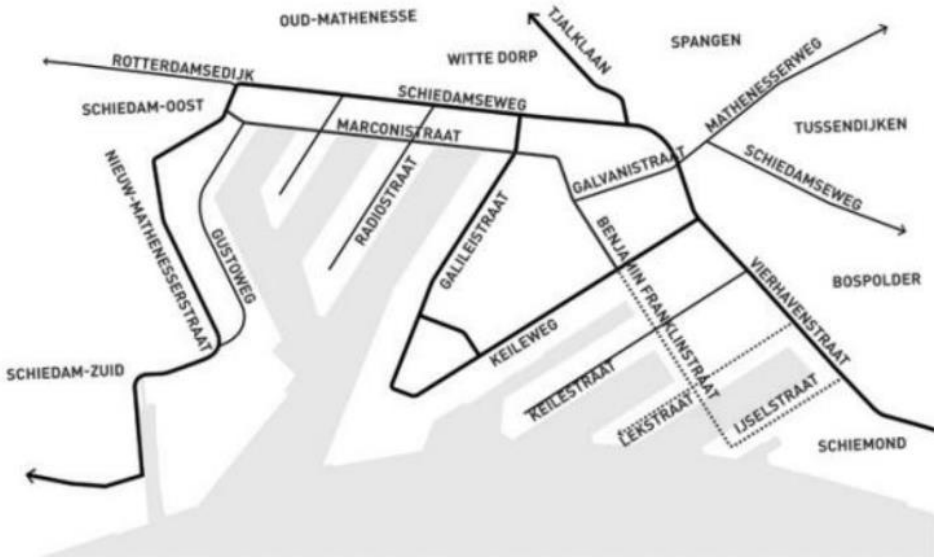


Figure 6 Street Network in M4H (Delva, 2019)

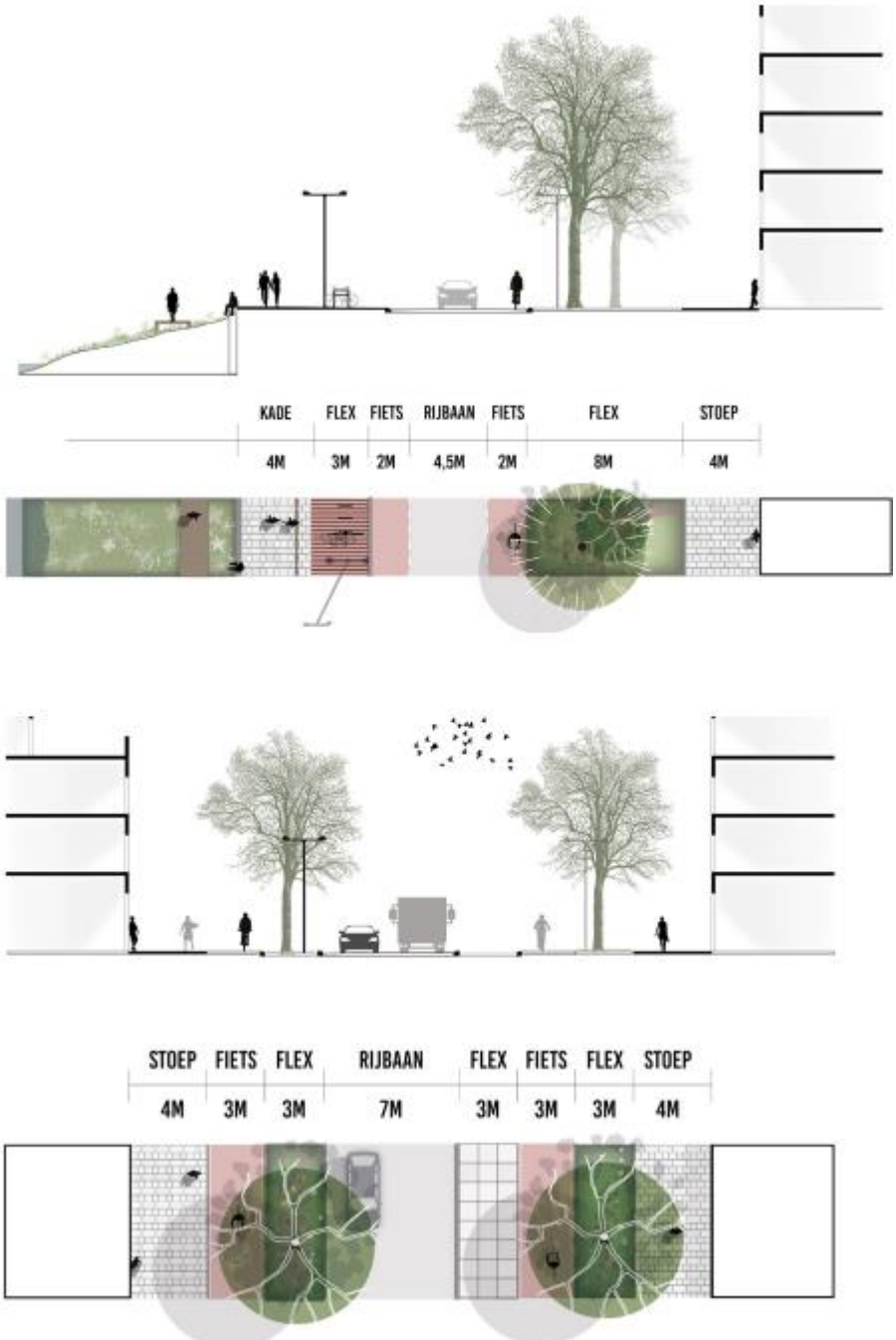


Figure 7 Concept Street Profiles M4H (Delva, 2019)

3. The Mobility Strategy

The goal of the mobility strategy in M4H is to prevent overload and promote sustainable alternatives. Without such measures, nearby roads and intersections, such as Marconiplein, risk becoming overloaded (Rotterdam Makers District, 2019).

The mobility strategy therefore primarily focuses on **promoting alternatives to private car usage, including bicycles, shared mobility options, and public transport.** Simultaneously, it aims to regulate car movements to and from the area (Rotterdam Makers District, 2019). Figure 8 visualises this strategy.

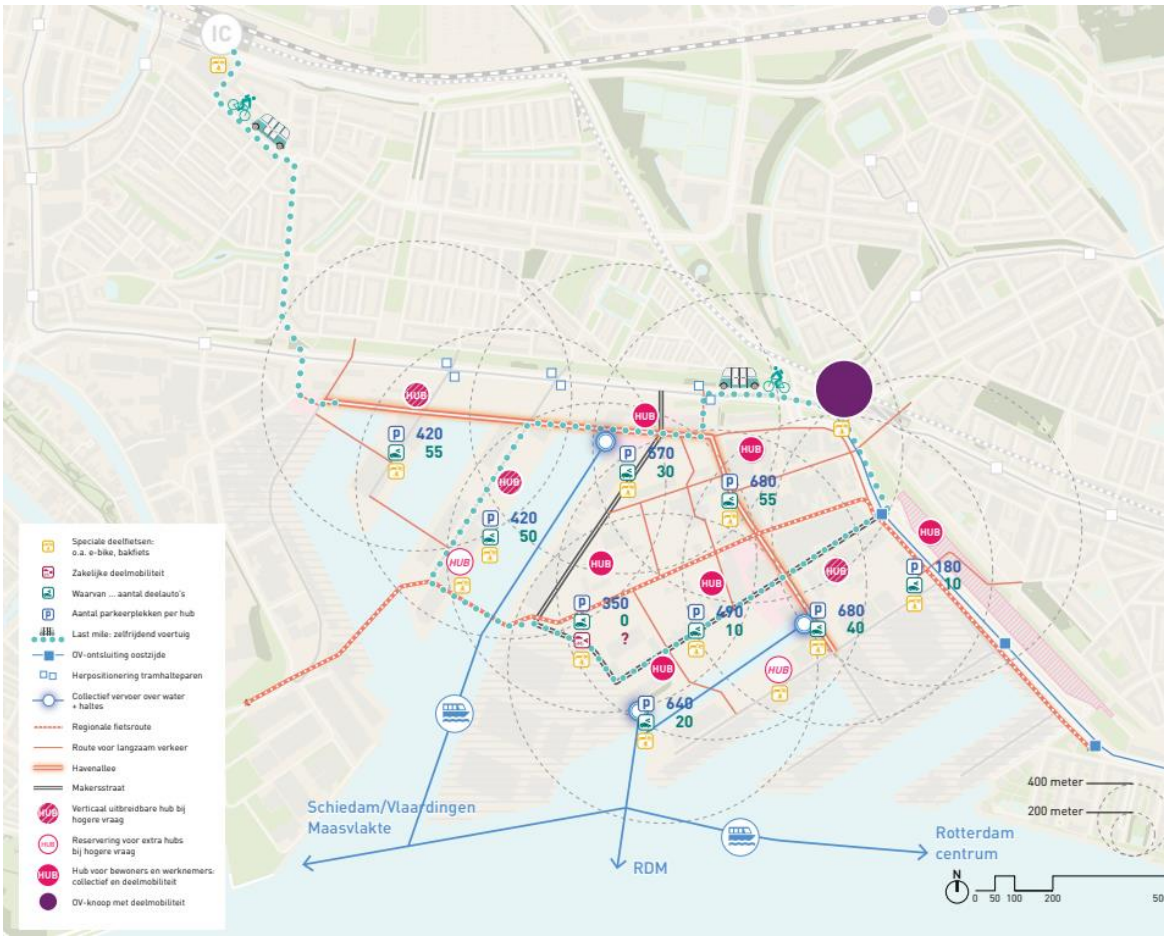


Figure 8 Mobility Strategy M4H (Delva, 2019)

Table 1 outlines the core approach to the mobility strategy in M4H according to the Mobiliteitsstrategie Merwe-Vierhavens (2022)document.

Table 1 Core Mobility Approach in M4H

Core Mobility Approach in M4H Based on the Mobiliteitsstrategie APPM Management Consultants et al. (2022)			
Proper organization of car and freight traffic in relation to slow traffic.	A dense network for cyclists and pedestrians, both within the area and connecting the area to the surroundings.	Collective (smart) transport systems such as bike-sharing, transportation by water, and first-last-mile solutions that connect Schiedam Centrum and Marconiplein with M4H.	No street parking, but the establishment of hubs. These hubs are established at regular intervals in the area and offer not only individual parking spaces but also shared mobility, package services, etc. These hubs can be combined with other collective services such as water collection, waste services, etc.

The concept aims to serve the various target groups for M4H. M4H will have the profile of an **innovative residential and working area** and therefore has six target groups:

Table 2 M4H Development Target Groups (APPM Management Consultants et al., 2022)

1.	Entrepreneurs/employees in the manufacturing industry who use vans and trucks for goods transport
2.	Entrepreneurs/employees who commute from home to work daily
3.	Residents of M4H who mainly travel within the city
4.	Residents of M4H who travel within the entire Randstad area
5.	Visitors of public functions in M4H
6.	Residents from surrounding neighbourhoods who use facilities in M4H
7.	*(The existing logistics-related companies in the port)*

Some of the **keys of the strategy are the reduction of individual ownership and individual use of cars and equipping publics paces for walking and cycling to different nodes for public transport that offer suitable alternatives.** Therefore, the mobility concept focuses on all forms of mobility (modalities) (APPM Management Consultants et al., 2022). The concept consists of the following components:

PEDESTRIANS AND BICYCLES

According to the mobility strategy document, a key success factor for the success of the mobility concept is that the public space is attractive for pedestrians. Walking a part of your journey adds liveliness and interaction to the streets. Pedestrians in M4H will be able to use a fine-meshed

network of roads, paths, and bridges; comfortable routes; good lighting; social safety, and the proximity of amenities(APPM Management Consultants et al., 2022).

The ambition is to make cycling the preferred mode of transport in M4H. This will be done through designing safe and appealing infrastructure that connects well with the rest of the city(APPM Management Consultants et al., 2022).

PUBLIC TRANSPORT AND LAST-MILE AND WATER TRANSPORTATION

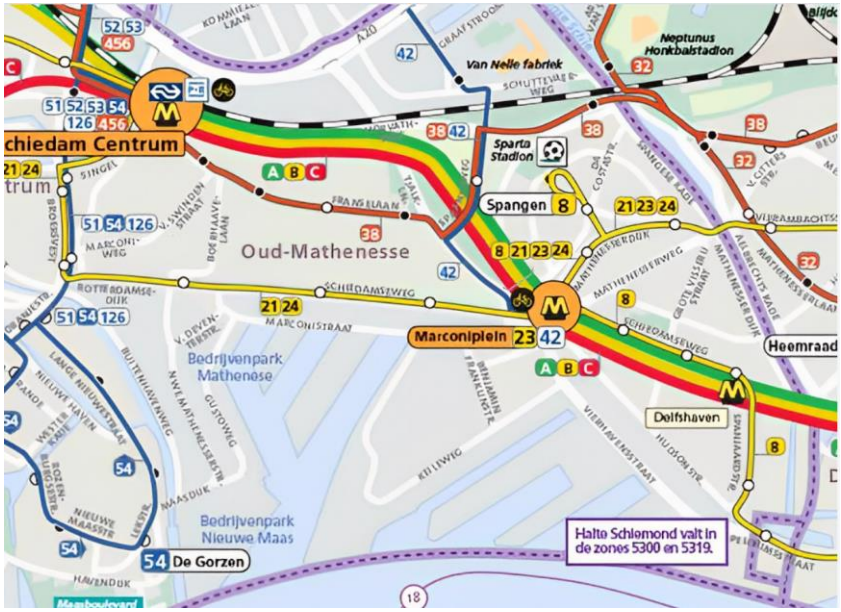


Figure 9 Public Transportation Network Around M4H (APPM Management Consultants et al., 2022)

The outskirts of M4H will be served by metro, tram, and bus lines (Figure 9). However, the implementation of a tram system within the area itself will be contingent upon the transformation of M4H into an urban hub (APPM Management Consultants et al., 2022).

Furthermore, the waterfront areas will benefit from two water taxi stops near Fruitvis and Kunst&Complex, along with a planned water bus stop in the future. These connections will provide access to destinations across the river (APPM Management Consultants et al., 2022).

Before a new tram line is implemented the public transport strategy will prioritize enhancing existing major routes and optimizing the last-mile connectivity from larger transit hubs (Figure 10). This will entail upgrading Marconiplein metro station and introducing on-site mobility services (APPM Management Consultants et al., 2022).

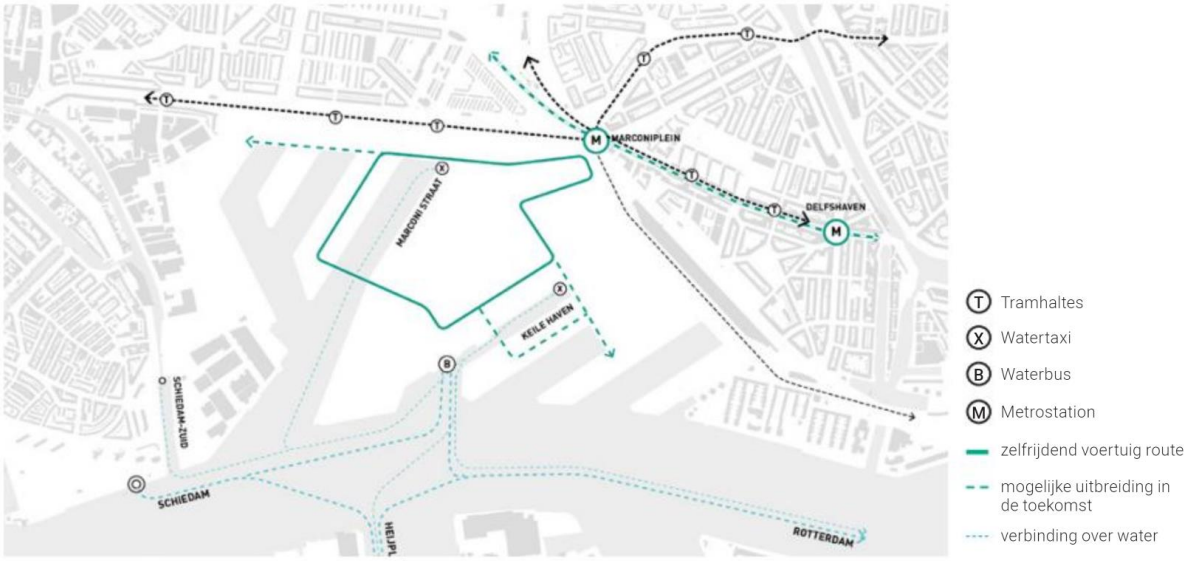


Figure 10 Connectivity to Public Transportation in M4H (Delva, 2019)

CARS

The aim is to limit the number of car trips in M4H to ensure that the area remains accessible in the future and maintains an attractive living environment. This choice also requires a focus on different modes of transport and a different, less dominant position of the car in the design of the area, both in terms of moving and parked cars (APPM Management Consultants et al., 2022).

Parking will not be permitted on the streets, nor will it be resolved individually on private plots. Instead, collective parking spaces will be established. This approach will enhance the pleasant look of the street environment, encourage walking and cycling, promote efficient use of space (daytime parking for employees, evening parking for residents, for example), facilitate shared mobility, and allow integration with energy services. In areas of high density, these will be above-ground built facilities, whereas in areas of lower density, parking lots will be used. It is expected that the area will host approximately 4.400 parking spots (APPM Management Consultants et al., 2022).

The parking facilities will become integral components of collective amenities, consolidated within "mobility hubs." These hubs will offer shared mobility, energy, and various other services utilized by businesses, residents, and visitors alike (Figure 11). They will represent crucial links in achieving the area's sustainability goals. Establishing hubs will require consistency and perseverance in hardware (building infrastructure), orgware (investment, development, management, operation), and software (provided services and supporting facilities). Being above-ground, **the hubs will allow for transformation into other functions in response to decreasing parking demand** (APPM Management Consultants et al., 2022).

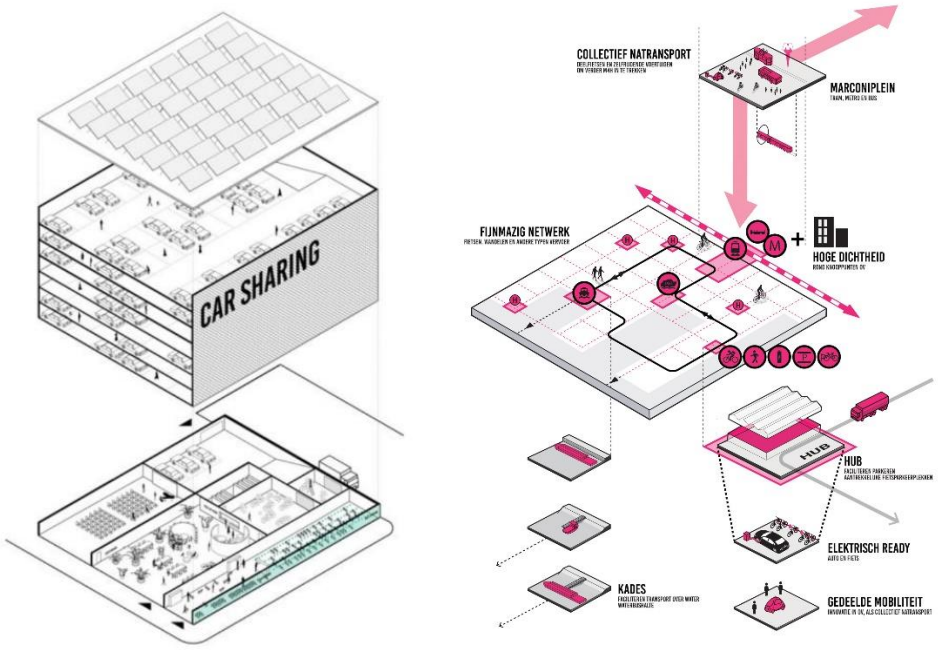


Figure 11 Mobility Hubs Framework

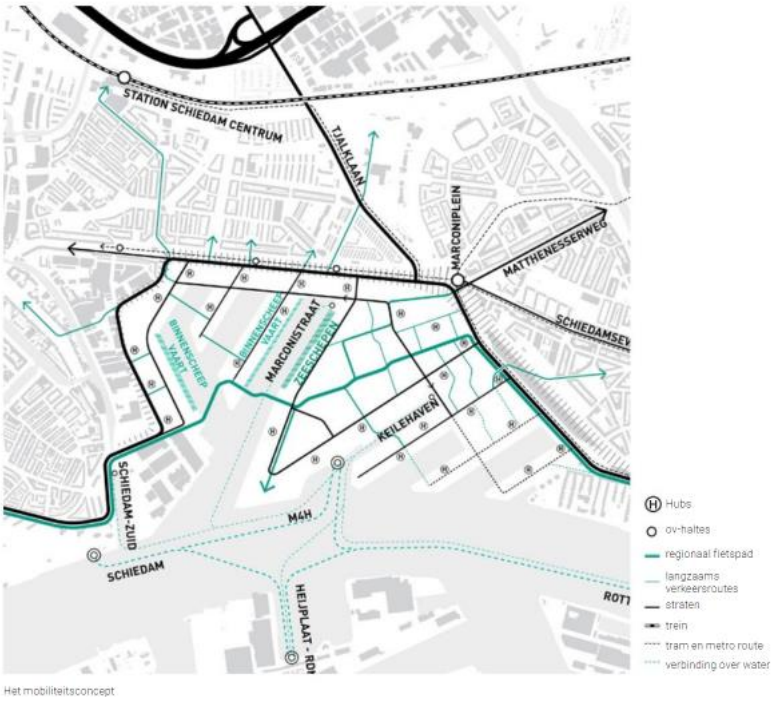
M4H will adhere to the parking policy of the Rotterdam municipality, which will set parking standards combined with deductions when alternative transportation forms are employed or well-facilitated, such as proximity to public transport, additional space for bicycle parking, car-sharing services, and availability of Mobility as a Service (MaaS) (APPM Management Consultants et al., 2022).

MOBILITY HUBS AND SHARED MOBILITY

It will be important that all users in M4H have access to a wide range of shared mobility options such as car-sharing, bike-sharing, and other forms of shared transportation. It is said that thanks to the large size of the area, it will be possible to make both station-based and free-floating shared mobility systems available. This will strengthen the first and last mile connections from the major public transport hubs and will offer users of M4H more choices. Users will be able to access all these mobility solutions through a Mobility as a Service (MaaS) platform (APPM Management Consultants et al., 2022).

Potential mobility hub locations have already been designated (Figure 12). The principle is that for all functions in the area, a hub should be available within a reasonable walking distance (maximum of 400 meters) (APPM Management Consultants et al., 2022). The choice of the location of the hub depends on:

- its location in relation to connecting roads;
- high density (more housing/companies per unit);
- the proximity of important points in the area (M4H, 2022).



Het mobiliteitsconcept

Figure 12 Mobility Hub Locations (Delva, 2019)

Although the design of the hubs has not yet been established, there are several factors that will need to be taken into consideration. According to the mobility strategy document hose are: routing, social safety, adaptability, attractive appearance, and combinations with other functions. Hubs should not be dark, remote parking garages or underground garages, but rather central, attractive spots in the neighbourhood (APPM Management Consultants et al., 2022).

Some of the current principles for the placement of hubs are:

- Utilizing existing parking facilities (Europoint and Dakpark) wherever possible to minimize initial losses on built parking;
- Improving access to public transport in the initial phase by introducing a shuttle bus (a feasibility study for this is still pending); and establishing good pedestrian and cycling routes to Marconiplein and the tram;
- Keeping space open for developments and using temporary facilities. These can also include surface-level hubs.
- Constructing the hubs in such a way that they can flexibly grow (or transform) with demand. This requires a suitable foundation and sufficient utility provisions during construction;
- Making the layout within the hub flexible so that the share of shared facilities can grow with demand. This requires collective use (not personal ownership) of parking spaces in the hubs and the possibility of charging electric cars and scooters;
- Centrally monitoring the use of these mobility facilities (parking, shared mobility, shuttle bus) and adjusting them according to usage (APPM Management Consultants et al., 2022)

Figure 13 Mood Board for the Development of Mobility Hubs in M4H (Delva, 2019)

4. Conclusion

The development and mobility strategy for the Merwe-Vierhavens (M4H) area in Rotterdam aims to create an innovative, sustainable, and inclusive urban environment. The project, led by the Municipality of Rotterdam and the Rotterdam Port Authority, focuses on transforming M4H into a dynamic mixed-use area that accommodates a blend of residential, cultural, commercial, and recreational functions. One of the main aspects of the transformation is the mobility strategy designed to reduce car dependency and promote sustainable and shared transportation options.

The core of the mobility strategy is the promotion of alternatives to private car usage. This includes the development of a dense network for cyclists and pedestrians, ensuring that these modes of transport are safe, attractive, and well-integrated with the rest of the city. The emphasis on cycling and walking is supported by the creation of inviting public spaces and well-lit, socially safe routes, making these active modes of transport the preferred choice for residents and visitors alike.

In addition to enhancing pedestrian and cycling infrastructure, the mobility strategy places a strong emphasis on shared mobility solutions. These include bike-sharing and car-sharing programs, which are facilitated through a Mobility as a Service (MaaS) platform.

The strategy also explores the use of water transport, with plans for water taxi stops and water bus services to improve accessibility along the waterfront.

Another key element of the M4H mobility strategy is the establishment of mobility hubs. These hubs will be strategically located to ensure that all functions in the area are within a reasonable walking distance (maximum of 400 meters) from a hub. Mobility hubs will serve as centralized points for various transportation services, including parking, shared mobility options, and other collective amenities such as package services, waste collection, and energy services.

The design of the mobility hubs will be guided by principles of flexibility and adaptability. Hubs should be constructed to accommodate changing demands, with the potential to transform into other functions as parking needs decrease.

In summary, the M4H development and mobility strategy is a plan that integrates sustainable and shared mobility solutions that aims to create a vibrant, accessible, and resilient urban community. By prioritizing cycling, walking, and shared transportation, and by establishing multifunctional mobility hubs, the strategy aims to reduce car dependency, mitigate congestion, and support the overall mobility transition.

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APPENDIX B

Socio-Demographic Neighbourhood Analysis

Nieuw-Mathenesse, Oud-Mathenesse, Witte Dorp, Spangen, Tussendijken, Bospolder

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1. Introduction

The information in this paper consists of an analysis of data sourced at Home - Onderzoek010. This is an open data platform managed by the Research and Business Intelligence department of the municipality of Rotterdam. The data provided on the website spans different topics for various parts of Rotterdam. For the purpose of this tstudy it has been filtered for neighbourhoods relevant to M4H, namely Nieuw-Mathenesse, Oud-Mathenesse, Witte Dorp (later in the research considered together with Oud-Mathenesse), Spangen, Tussendijken, and Bospolder.

The results of this analysis are also supported with street observations performed on a warm day in March 2024.

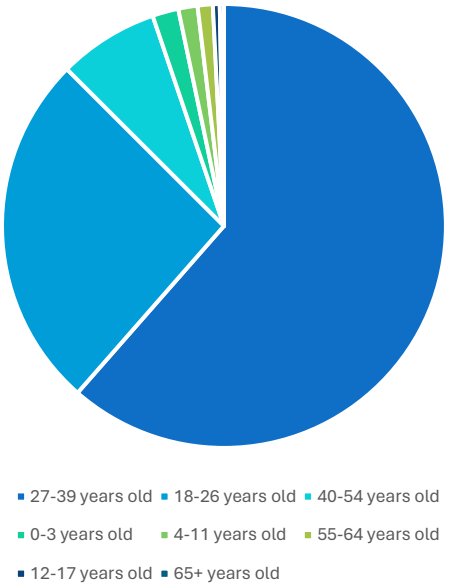
2. Nieuw-Mathenesse

Figure 1 Nieuw- Mathenesse Location

Figure 2 Nieuw- Mathenesse

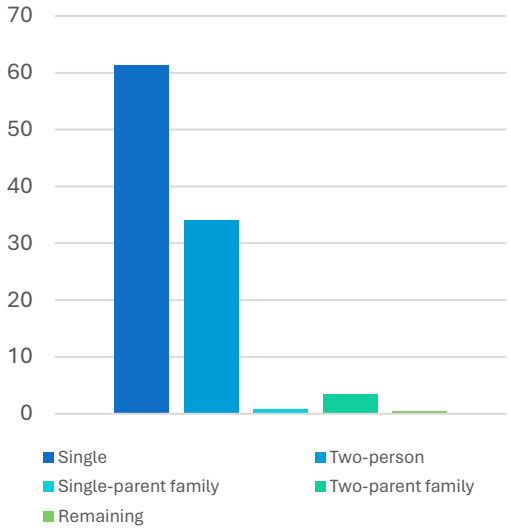
Nieuw- Mathenesse is the neighborhood that new plans are made for. Currently it is an industrial area with shipping functions, offices and test sites. At this moment there are not a lot of people living in Nieuw- Mathenesse. Records showed approximately 1100 inhabitants in 2022.

Age Group Buurt Nieuw Mathenesse



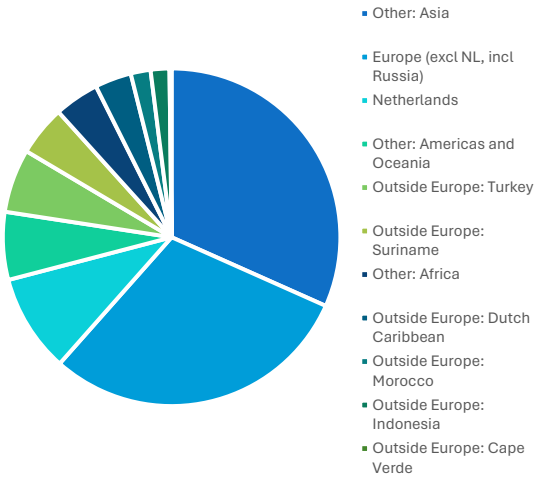
The dominant age group among the residents are 27-39 year old people followed by 18-26 years old and 40-54 years old people.

Household Composition - Nieuw Mathenesse



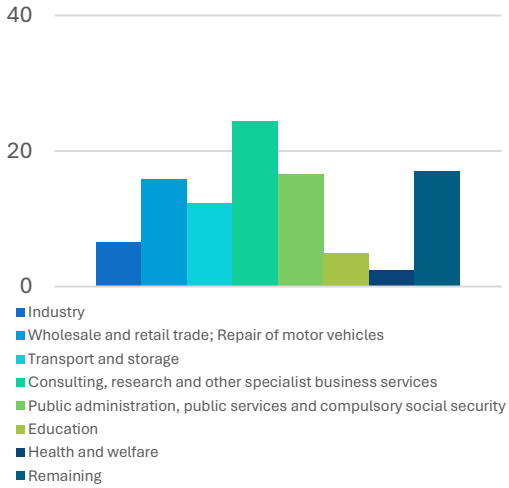
Most households in Nieuw-Mathenesse are single- person households followed by single-parent families.

Population Origin Buurt Nieuw Mathenesse

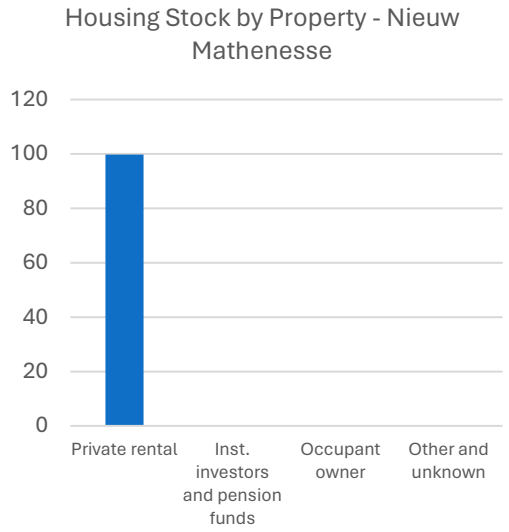


Nieuw- Mathenesse is characterized by a diverse population origin. A lot of residents come from Asian or European countries backgrounds.

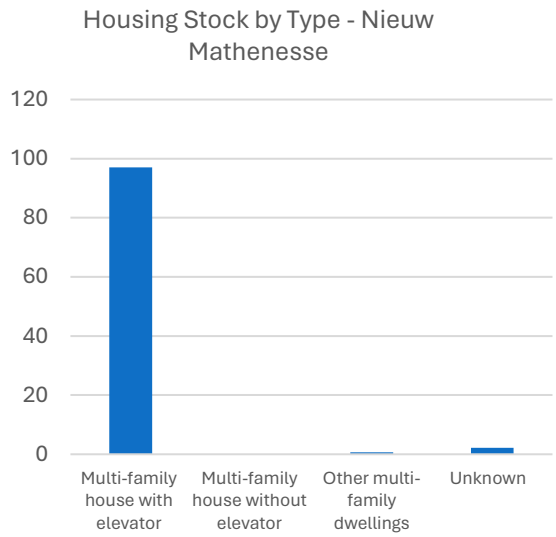
Employed Persons by Sector -Nieuw Mathenesse



Majority of people in Nieuw-Mathenesse are employed in Consulting, research and other specialist business services. Some also work in public administration or wholesale or retail trade.



Almost all of the properties in Nieuw-Mathenesse are private rental properties.



Almost all properties in Nieuw- Mathenesse are multi-family houses with elevators (eg. Lee Towers) or other multi-family dwellings (like the house in Figure 2).

In summary, despite its industrial character, the neighborhood is home to approximately 1100 inhabitants as of 2022, with a diverse demographic composition. Dominated by single-person households and single-parent families, Nieuw-Mathenesse reflects a mix of cultural backgrounds, with residents primarily employed in consulting, research, and specialist business services. Housing primarily comprises private rental properties, with multi-family dwellings like Lee Towers being a notable feature of the landscape.

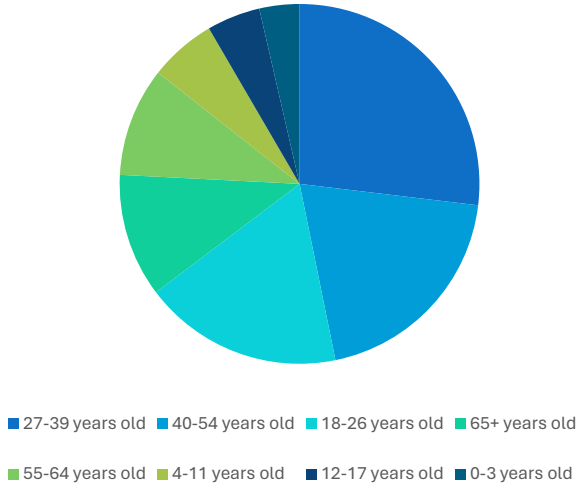
3. Oud-Mathenesse

Figure 3 Oud-Mathenesse Location

Figure 4 Oud-Mathenesse

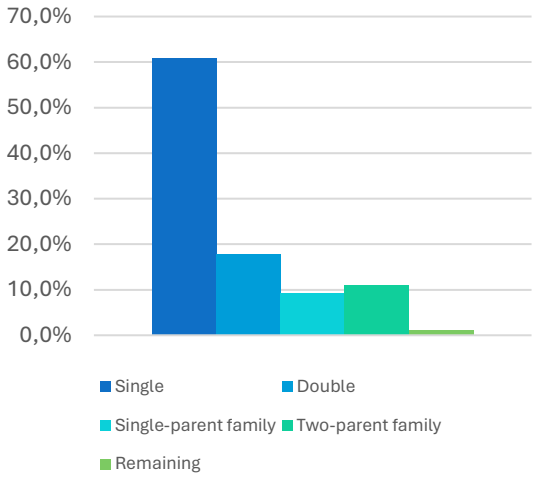
Oud-Mathenesse is a neighborhood just north of M4H. It is characterized by vibrant walkable streets, greenery, playgrounds and visible presence of community engagement.

Age Group Buurt Oud Mathenesse



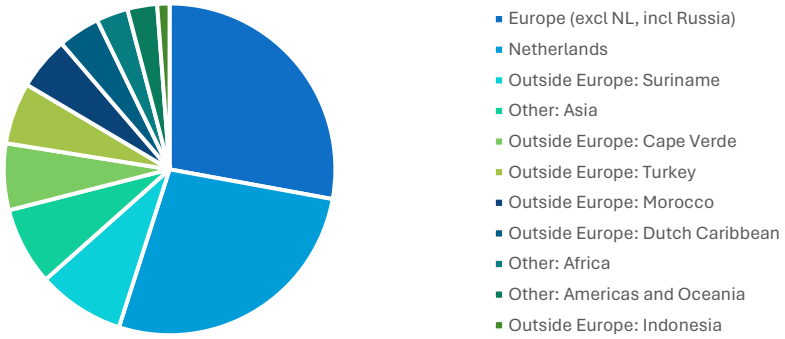
Oud-Mathenesse is a neighborhood in which 27-39, 40-54, 18-26 years old age groups are most present. This makes it a neighborhood with a lot of young population.

Household Composition Buurt Oud Mathenesse



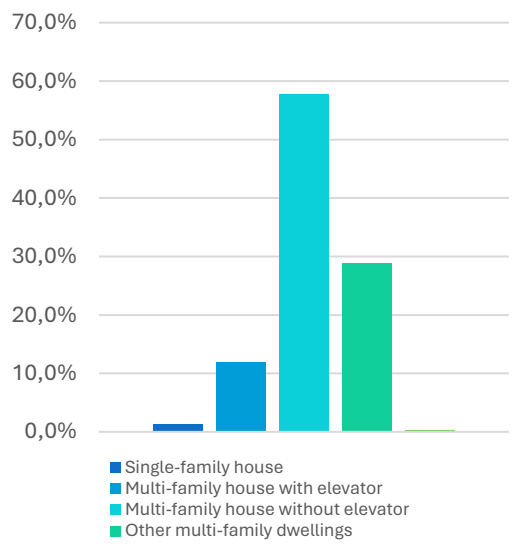
Oud-Mathenesse consists mostly of Single-family households. There are also some double and couple with children households.

Population Origin Buurt Oud Mathenesse



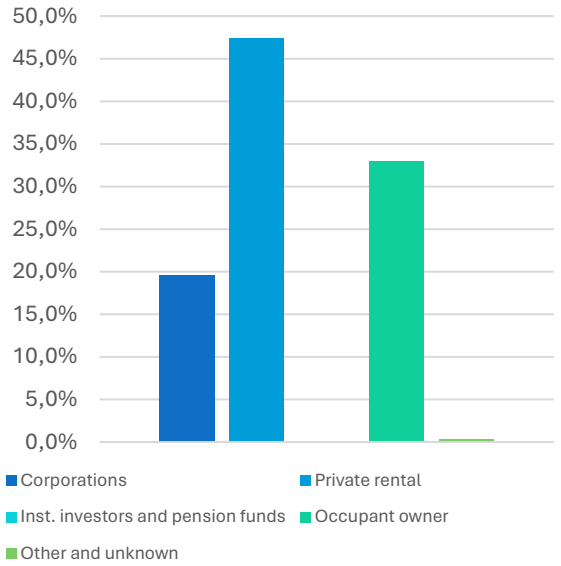
There are a lot of residents with European migration backgrounds in Oud-mathenesse. This group is followed by Dutch and Suriname demographic backgrounds.

Housing Stock by Type Buurt Oud Mathenesse



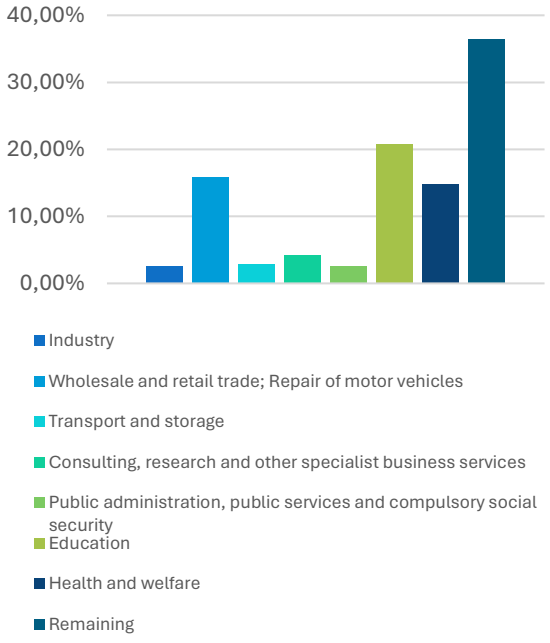
Oud-Mathenesse is mostly characterized by multi-family houses without elevator and other multi-family dwellings.

Housing Stock by Property Buurt Oud Mathenesse



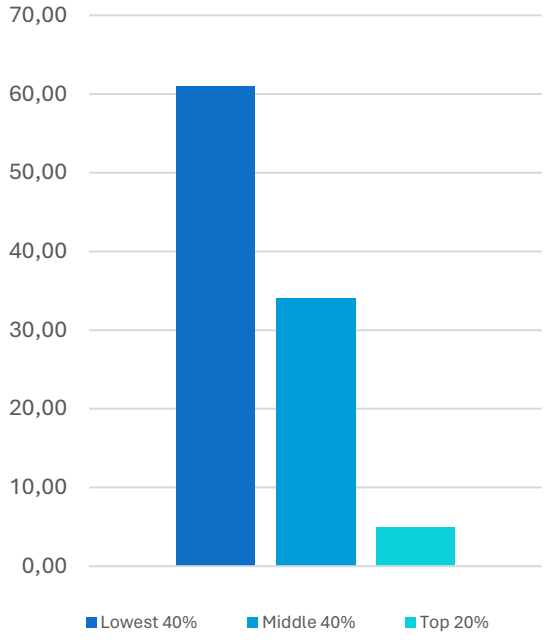
Most properties in Oud-Mathenesse are private-rental properties. This number is followed by owner-occupier houses and corporate rental.

Employed Persons by Sector Oud Mathenesse



Most people living in Oud-Mathenesse work in the education sector. This group is followed by people working in the wholesale and retail sector and health and welfare sector.

Standardized Household Income Buurt Oud Mathenesse



Majority of the households in Oud-Mathenesse are low-income households however, some mid- and high-income households are also present.

To conclude, with a predominantly youthful population, particularly in the age groups of 27-39, 40-54, and 18-26, Oud-Mathenesse is primarily comprised of single-family households, although

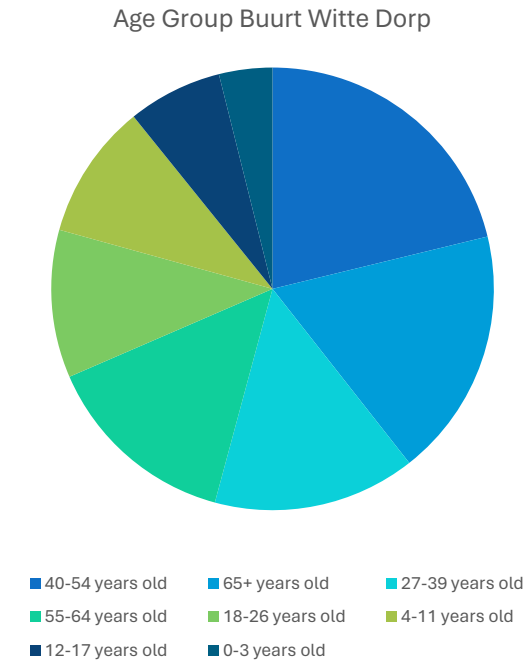
there are also double households and couples with children households. The community reflects a diverse mix of European, Dutch, and Surinamese demographic backgrounds. Housing in Oud-Mathenesse is predominantly multi-family dwellings without elevators, with private rental properties being the most common housing type. Employment in the education sector is prevalent among residents, followed by those working in wholesale and retail, as well as health and welfare sectors.

4. Witte Dorp

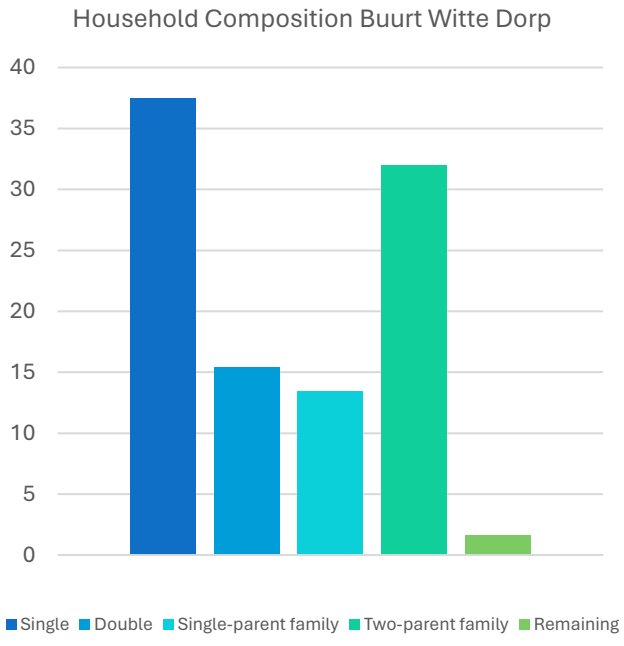
Figure 5 Witte Dorp Location

Figure 6 Witte Dorp

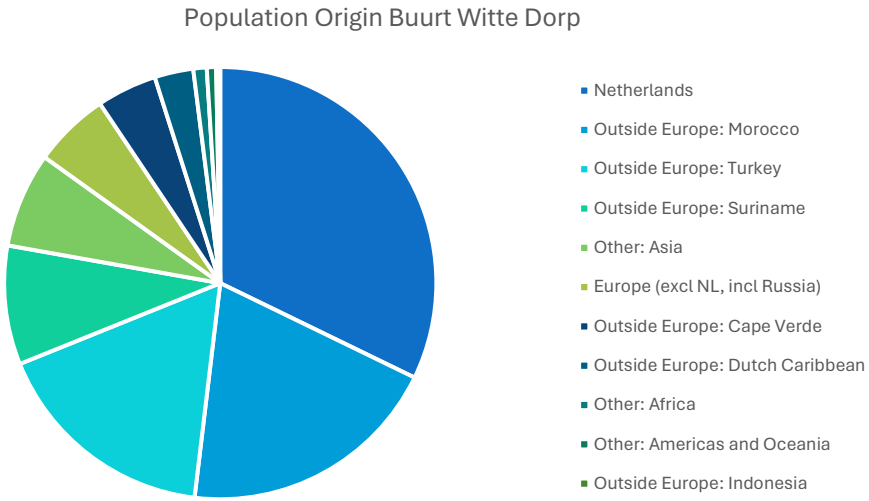
Witte Dorp is a small area often mentioned together with Oud-Mathenesse. Historically it was built for the workers of the Merwe-Vierhavens port. Currently it is a quiet place with little traffic and a sense of community visible on the streets.



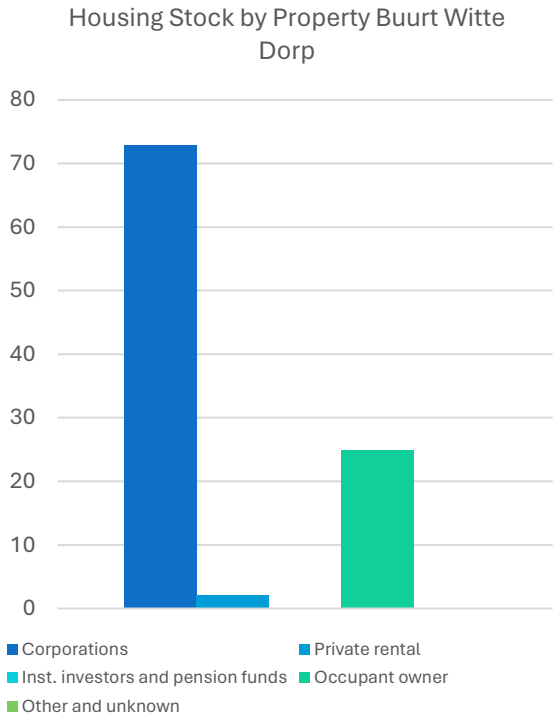
Majority of the populationin Witte Dorp is over 40 years old with a large share of people above 65 years old. There is also a significant share of people between 27-39 years old.



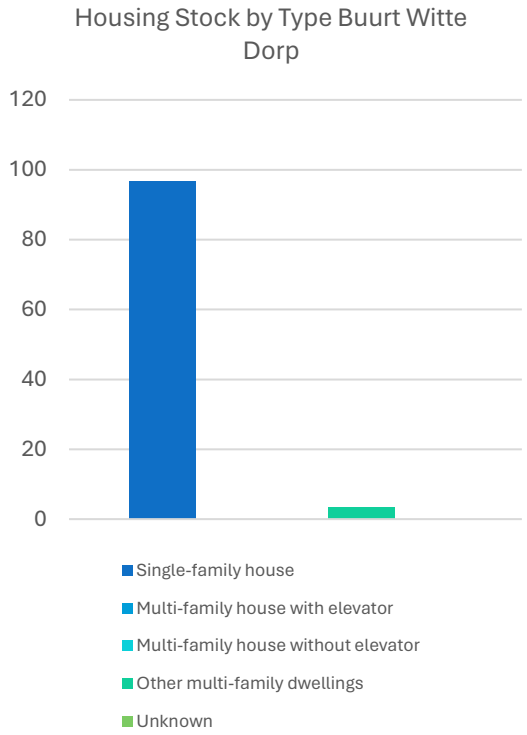
Most households in Witte Dorp are single-family households followed by a couple with children households.



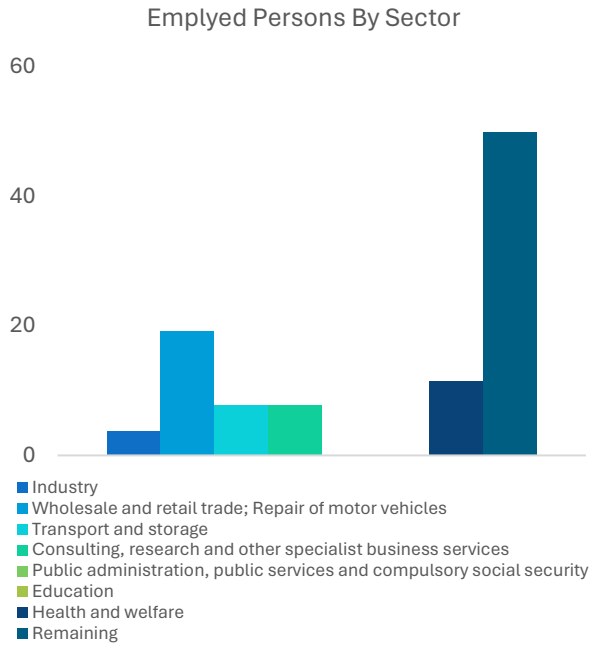
Most of the population in Witte Dorp is of Dutch origin. However, there is also a large share of people with Moroccan or Turkish backgrounds.



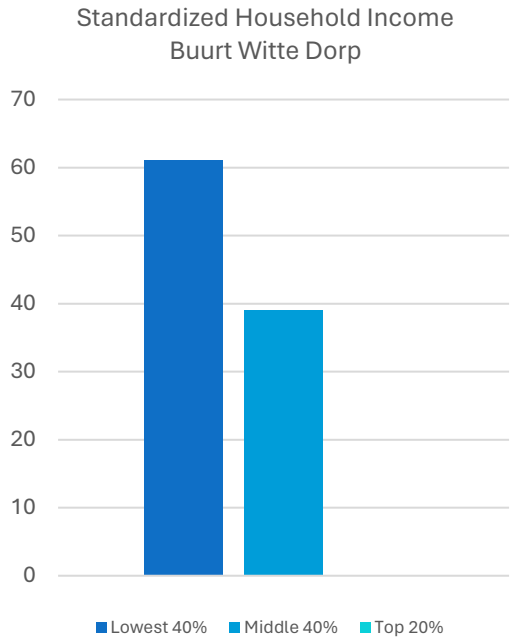
Most housing in Witte Dorp is corporate rental or occupied by owners.



Most of the housing in Witte Dorp is single- family houses.



Most people living in Witte Dorp have professions not specified by the data. However, there is also a large share of people working in wholesale and retail trade.



Witte Dorp is mostly characterized by households of low income. However, there is also a share of households with middle income.

To summarize, the demographic makeup of Witte Dorp leans towards an older population, with a significant portion being over 40 years old, including a big proportion above 65 years old, alongside a representation of individuals aged 27-39. Single-family households are prevalent in Witte Dorp, followed by households consisting of couples with children. The population is a blend of Dutch with sizable communities of Moroccan or Turkish descent. Housing predominantly comprises corporate rental properties or owner-occupied residences, with single-family houses being the predominant housing type. Employment data indicates a diverse range of professions among residents, with a notable presence in wholesale and retail trade. Socio-economically, Witte Dorp primarily comprises households with low-income brackets, although there is also a segment with middle-income levels.

5. Spangen

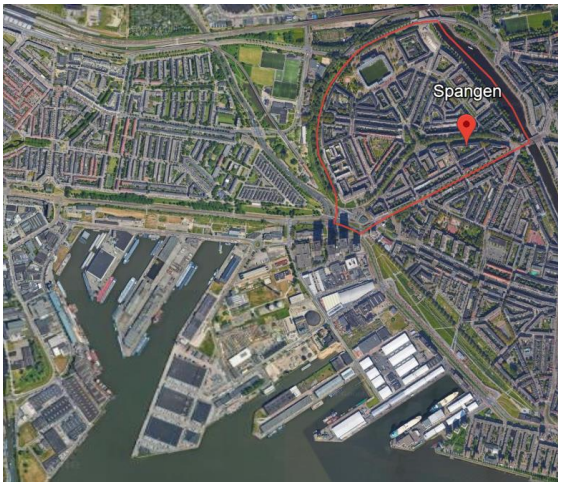
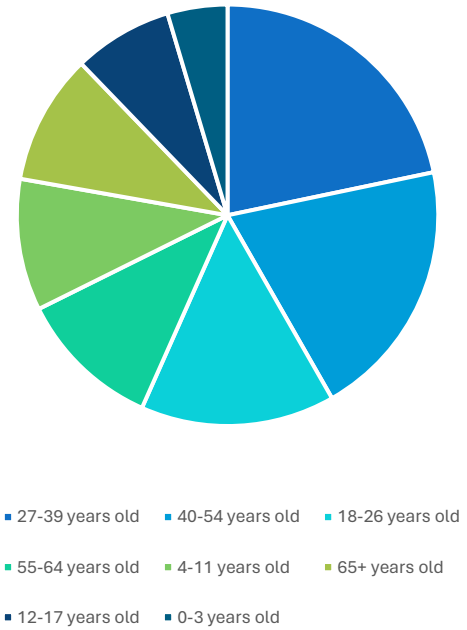


Figure 7 Spangen Location

Figure 8 Spangen

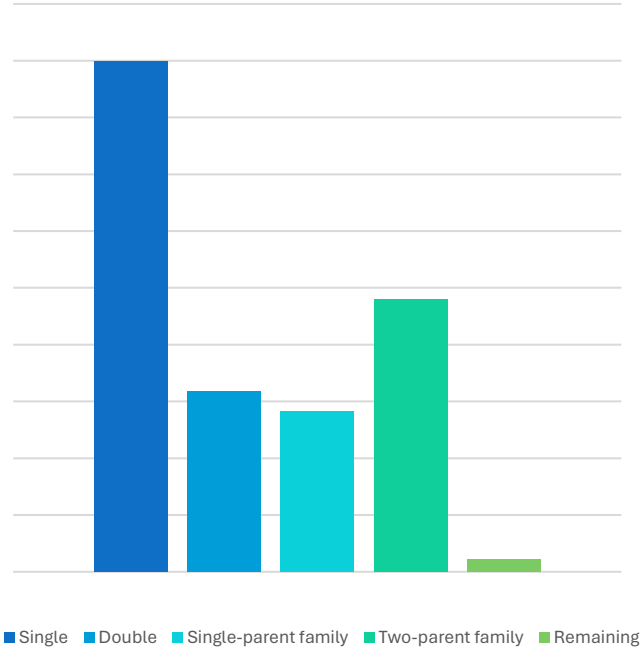
Spangen is a vibrant area with a lot of green spaces, vibrant shopping streets, playgrounds and a large share of families with children. There are some sport facilities in this neighborhood that attract people from surrounding areas.

Age Group Buurt Spangen

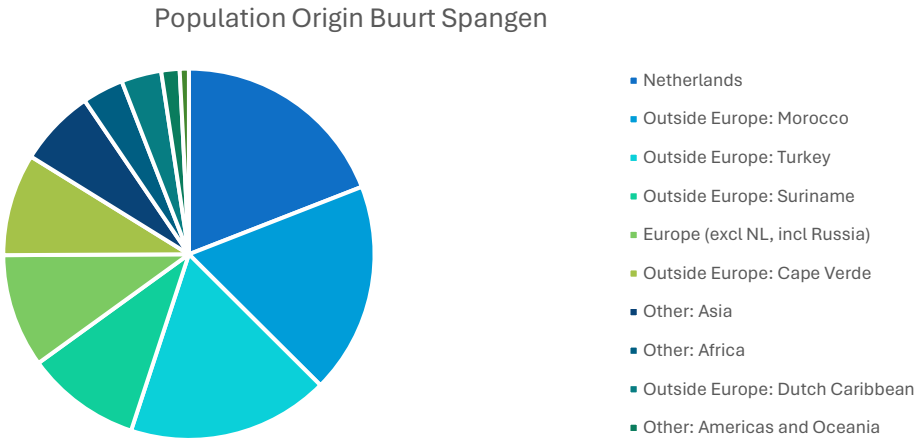


There are mostly 27-39, 40-54, 18-26 years people living in Spangen. There is a large share of children/teenagers (up to 17 years old) in the whole of the neighborhood.

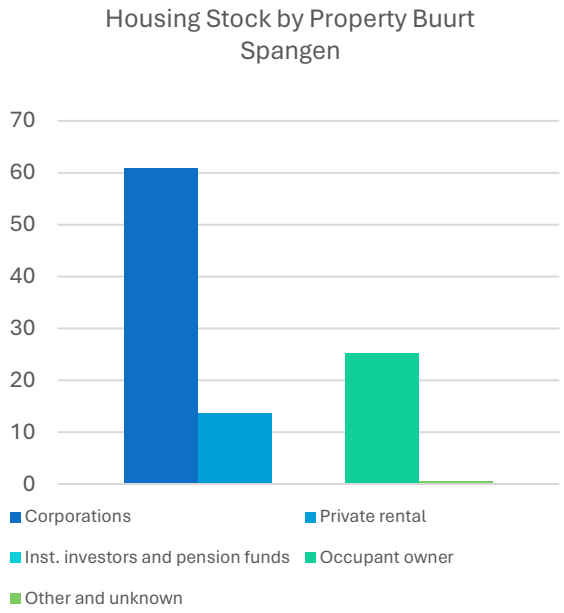
Household Composition Buurt Spangen



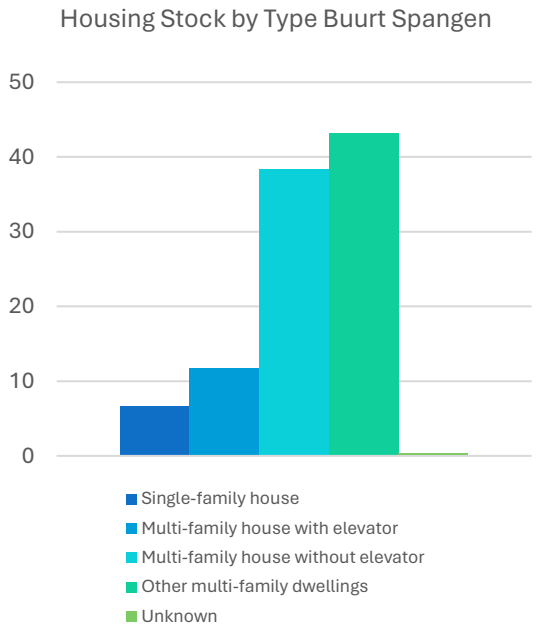
Most households compose of single persons or two-parent families.



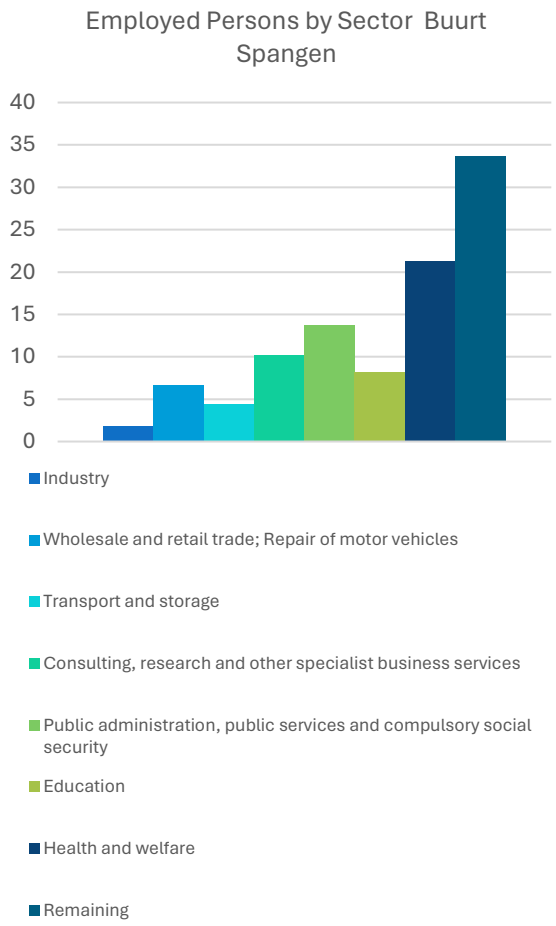
Most of the population in Spangen is of Dutch origin. However, there is also a large share of people with Moroccan or Turkish backgrounds.



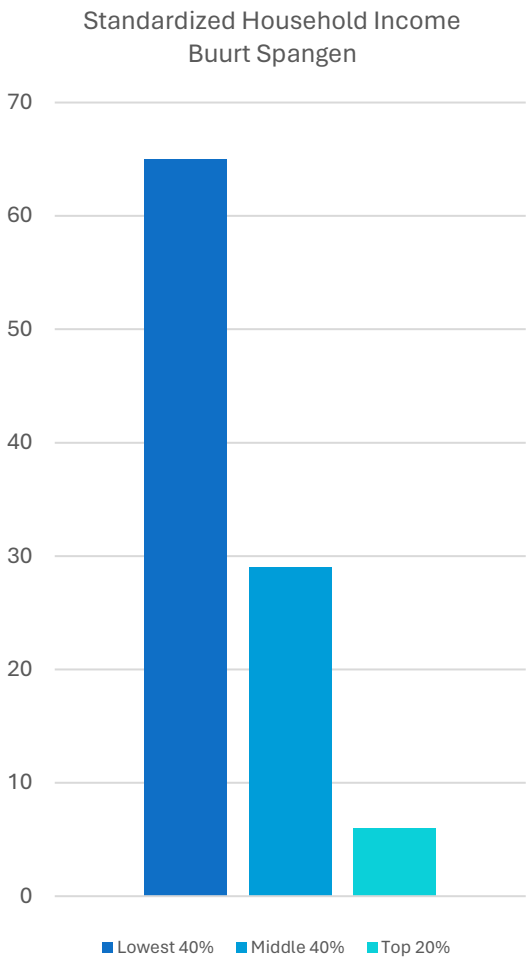
Most properties in Spangen are corporate rental properties.



Most of the housing in Spangen is multi-family housing (with elevators).



Most people living in Spangen are employed in sectors not specified by the data. There are people mostly employed in health and welfare, public services, consulting, research, and other specialist business services.



Majority of households in Spangen are low-income. however, there is also a share of households with middle-income and even some high-income households.

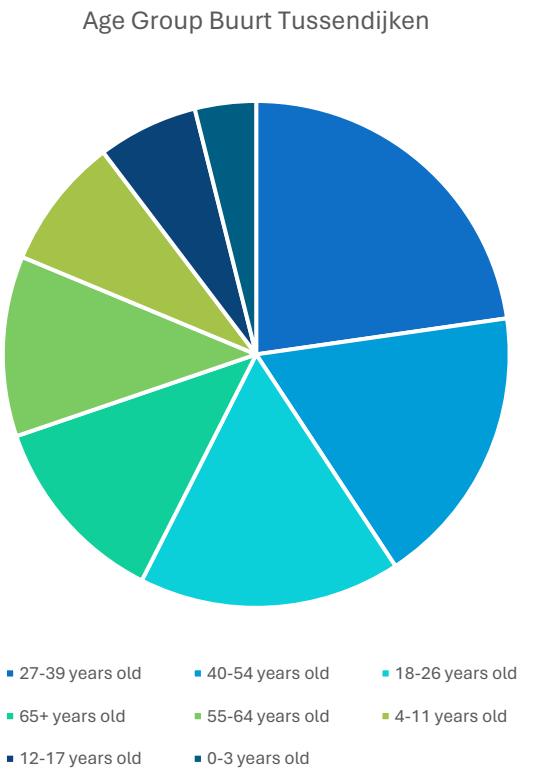
In summary, the demographic composition of Spangen primarily comprises individuals aged 27-39, 40-54, and 18-26, with a notable presence of children and teenagers throughout the neighborhood. Household structures predominantly consist of single individuals or two-parent families. While the majority of the population in Spangen is of Dutch descent, there is also a significant representation of individuals with Moroccan or Turkish backgrounds. Housing in Spangen is largely comprised of corporate rental properties, with multi-family housing, often equipped with elevators, being the predominant housing type.

6. Tussendijken

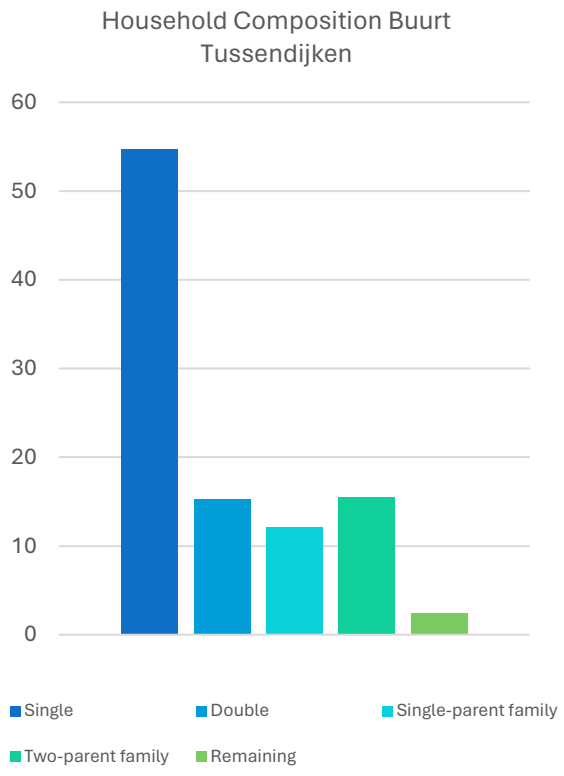
Figure 9 Tussendijken Location

Figure 10 Tussendijken

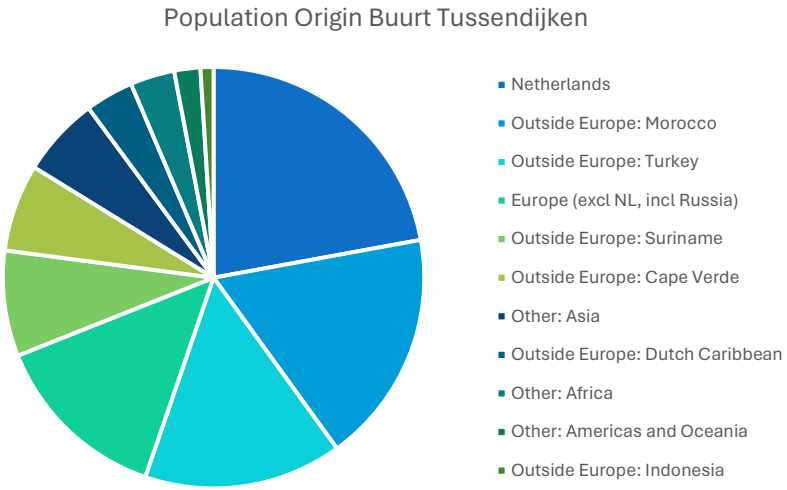
Tussendijken is a vibrant area with playgrounds and a lot of people present on the streets. It is dense yet green.



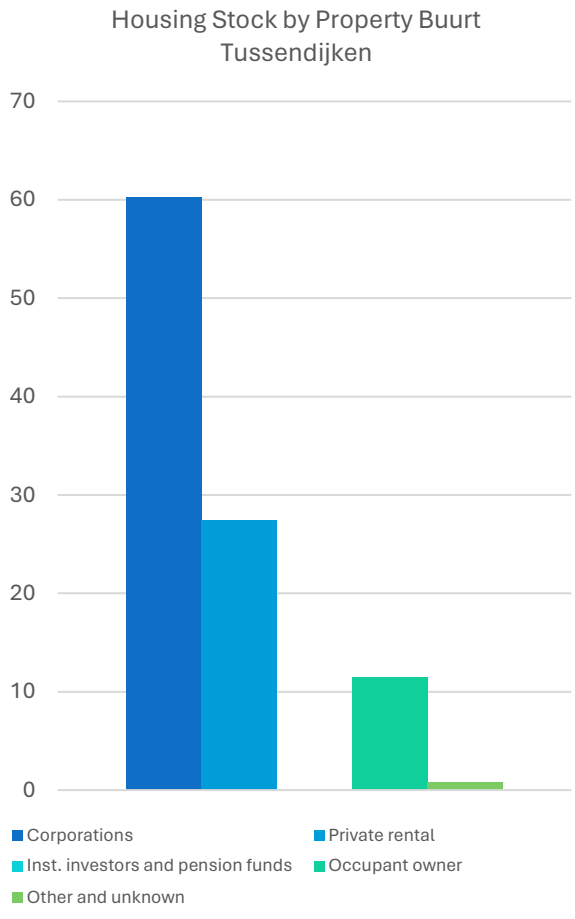
Most people living in Tussendijken are 27-39, 40-54, 18-26 years old. There is also a large number of people over 65 years old and a big number of children up to 17 years old in total.



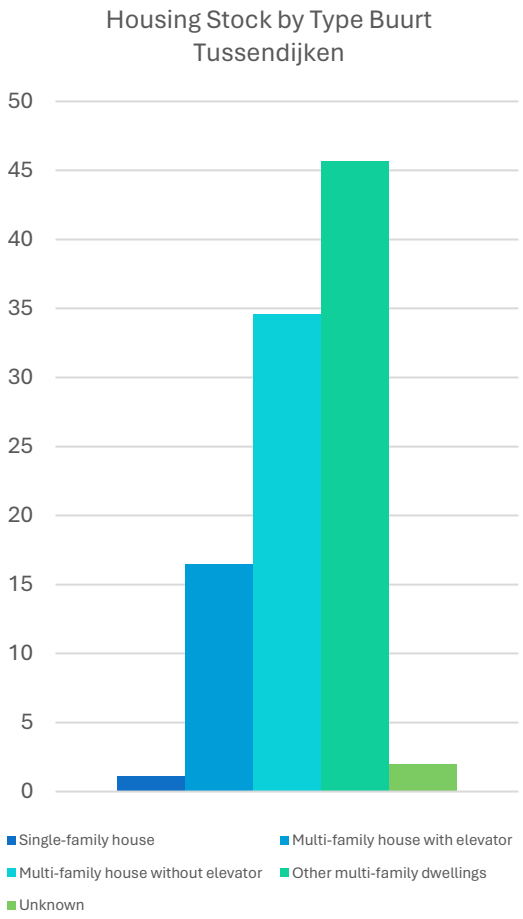
Most households in Tussendijken are single-family households. Next, there are single-parent families and two-person households.



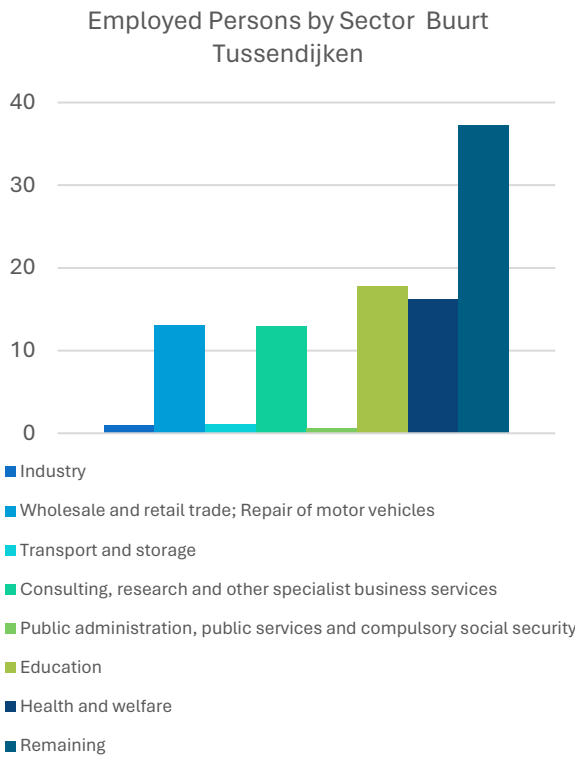
Most people living in Tussendijken have Dutch origin. There are also people of Morrocan, Turkish, and other European countries backgrounds.



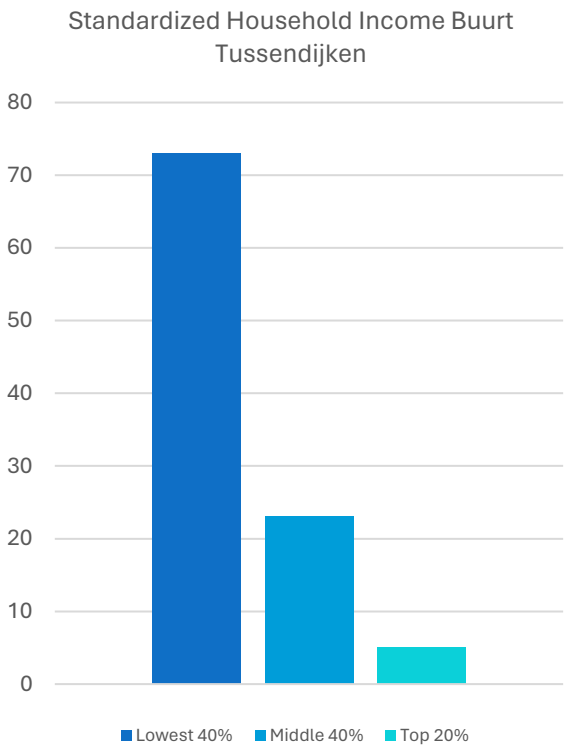
Most housing in Tussendijken is corporate-rental. There is also some private rental households and some houses occupied by owners.



Most houses in Tussendijken are various types of multi-family dwellings.



Most people living in Tussendijken are employed in sectors not specified in the data. There are a lot of people working in Education, health and welfare, consulting, or wholesale.



Majority of households in Tussendijken are low-income. however, there is also a share of households with middle-income and even some high-income households.

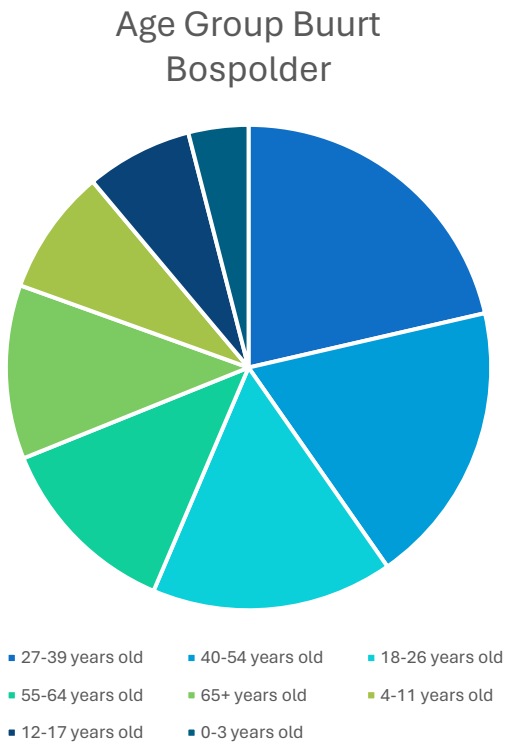
In conclusion, the demographic landscape of Tussendijken is diverse, with significant representation across various age groups, including individuals aged 27-39, 40-54, 18-26, and a notable presence of both elderly residents and children. The predominant household structure in Tussendijken comprises single-family households, followed by single-parent families and two-person households. While the majority of residents in Tussendijken have Dutch origins, the neighborhood is represented with inhabitants coming from Moroccan, Turkish, and other European backgrounds. Corporate rental properties constitute the majority of housing options in Tussendijken, with a mix of private rental and owner-occupied residences also present. The housing landscape primarily comprises various types of multi-family dwellings, catering to the diverse needs of the community. Employment sectors among Tussendijken residents span a wide spectrum, with a notable presence in education, health, welfare, consulting, and wholesale trade. While the neighborhood predominantly consists of low-income households, there is also a proportion of middle and high-income households contributing to the socioeconomic diversity of Tussendijken.

7. Bospolder

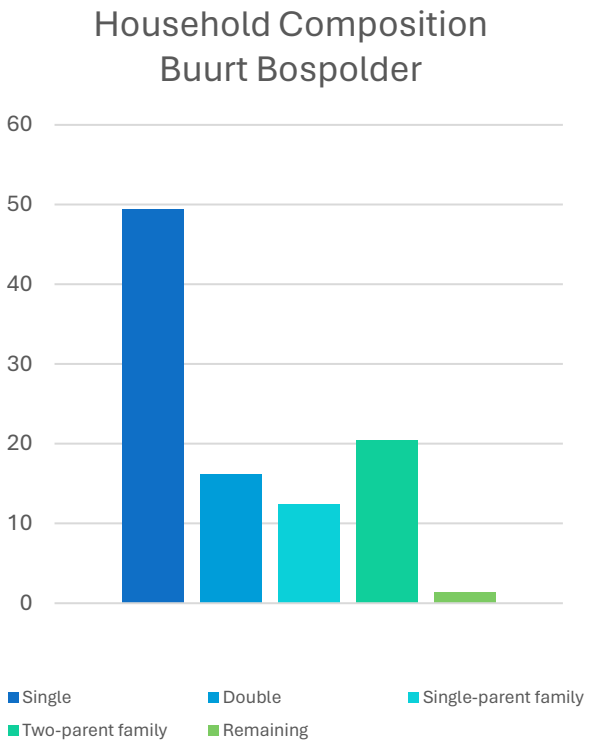
Figure 11 Bospolder Location

Figure 12 Bospolder

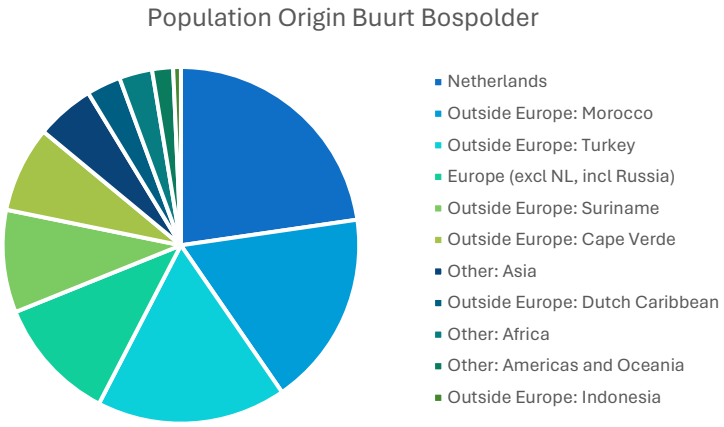
Bospolder is a lively neighborhood with a lot of activites on the streets. There are not only shopping streets, playgrounds but also community centers and visible presence of community engagement. For example, figure 12 shows an interaction of neighbors and their children on one of the streets.



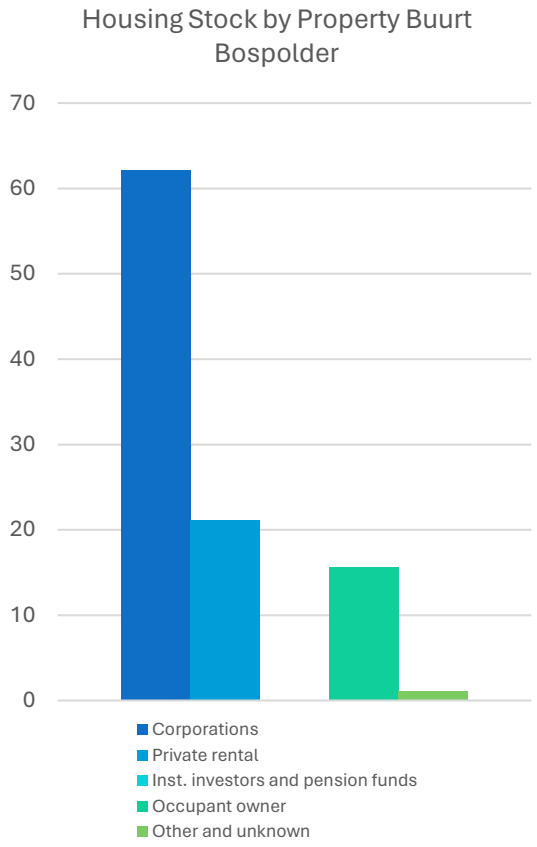
Most people living in Bospolder are 27-39, 40-54, 18-26 years old. There is also a large number of people of over 65 years old and a big number of children up to 17 years old in total.



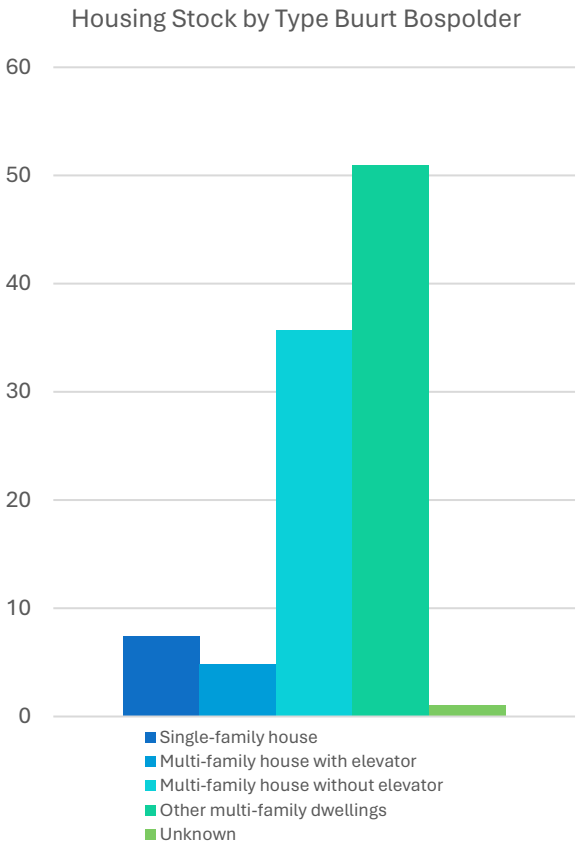
Most households in Bospolder are single-family. They are followed by two-parent family households and two-person households.



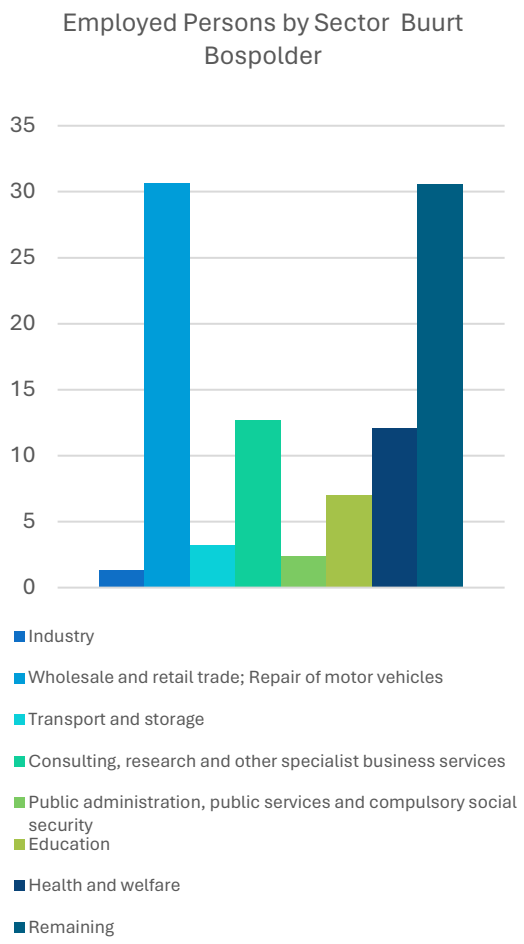
Most people living in Bospolder have Dutch origin. There are also people of Morrocan, Turkish, and other European countries backgrounds.



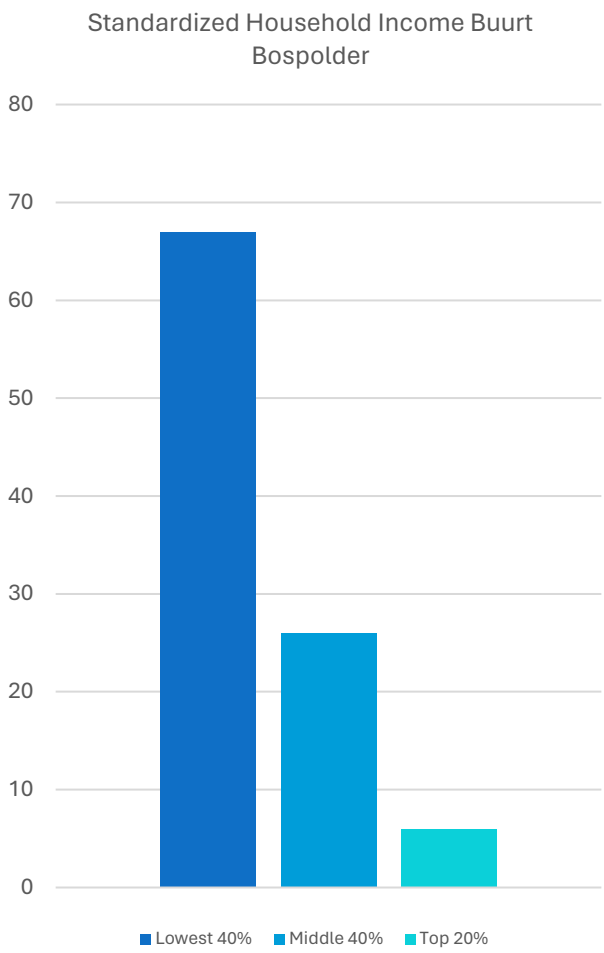
Most housing in Bospolder is corporate-rental. There is also some private rental households and some houses occupied by owners.



Most houses in Bospolder are various types of multi-family dwellings.



There is a large share of people working in the wholesale and retail trade sector in Bospolder. This group is followed by people working in consulting research and health and welfare.



Majority of households in Tussendijken are low-income. however, there is also a share of households with middle-income and even some high-income households.

In summary,the diverse population in Bospolder spans various age groups, with a predominant presence of single-family households. While Dutch residents form the majority, Bospolder is also represented by residents with inhabitants from Moroccan, Turkish, and European backgrounds. Housing options primarily consist of corporate rentals, with multi-family dwellings dominating the landscape. The neighborhood sustains a workforce focused on wholesale and retail trade, alongside consulting, research, and health sectors. While predominantly low-income, Bospolder also hosts middle and high-income households, adding to its socioeconomic diversity.

8. Conclusion

This paper showed an overview of the socio-economic profiles of various neighbourhoods surrounding the M4H district in Rotterdam, offering an understanding of their demographic compositions, housing structures, and employment landscapes.

The neighbourhoods, while diverse in their individual characteristics, are interconnected by a shared ethos of community engagement and vibrant urban life.

Nieuw-Mathenesse, though primarily an industrial area, shows a community with a diverse population engaged in consulting, research, and specialist business services. Oud-Mathenesse, just north of M4H, is an area full of lively streets and green spaces, fostering a youthful population primarily employed in education and retail sectors. Witte Dorp, historically linked to the Merwe-Vierhavens port, offers a tranquil environment for its residents, characterized by single-family houses and corporate rentals. Spangen, with its vibrant atmosphere and family-friendly amenities, serves as a hub for residents of various ages and backgrounds.

Tussendijken, characterized by greenery and community engagement initiatives visible on the streets, hosts a diverse population, primarily engaged in education, healthcare, and wholesale sectors. Bospolder, presents very similar characteristics.

In conclusion, the common characteristics of these neighbourhoods are a large share of young population, families with children, and single-person households. All these neighbourhoods are culturally diverse and often the majority of households are low-income. However, field observations shown that in all neighbourhoods there is a strong sense of community and a lot of activities taking place on the streets.

APPENDIX C

Mobility Patterns in Nieuw-Mathenesse, Oud-Mathenesse, Spangen, Tussendijken, and Bospolder.

Marta Nosowicz

Contents

Table of Figures

1. Introduction

The data analysed in this report originates from the Open Data Archive of the Data Archiving and Networked Services (DANS). Acquired upon request from the DANS repository (DANS Data Station Social Sciences and Humanities), the dataset (combined_filtered_data) consists of three collections from years 2020, 2021, and 2022, to improve the accuracy of the analysis.

Since 1978, the Central Bureau of Statistics (CBS) has conducted extensive research on the mobility patterns of individuals across the Netherlands. One of the key studies conducted by CBS is the Onderzoek Onderweg in Nederland (ODiN), aimed at providing valuable insights into the daily travel behaviours of the Dutch population.

The ODiN study encompasses a foundational national survey alongside supplementary investigations. The core survey entails a continuous examination of Dutch residents' travel behaviours, focusing on a specific day of the year. Respondents provide details regarding their travel destinations, purposes, modes of transportation, and travel durations. Additionally, the survey collects data on topics such as bicycle ownership, transportation usage, education, and social demographics. Supplementary data, including vehicle ownership and driver's license information, are linked from existing registries (CBS, 2023).

For the scope of this master thesis, the dataset was filtered to include responses from residents of specific neighbourhoods around M4H, namely Nieuw-Mathenesse, Oud-Mathenesse, Spangen, Tussendijken, and Bospolder identified by the respondents' residential postcodes (variable WoPC must equal 3029, 3028, 3027, 3026, 3025, 3024) following data filtering and integration across the three datasets, a total of 2305 records were remained for analysis.

This report aims to explore mobility patterns in neighborhoods surrounding Merwe-Vierhavens by examining variables such as trip purposes (MotiefV, KMotiefV), travel modes (Hvm), travel distances (KAfstV), trip durations (KReisduur),), and trip destinations (AankPC) combined with for example household compositions (HHSam) or income (HHBestInkG).

The sections below provide a detailed analysis of the findings derived from this dataset.

2. Trip Purposes

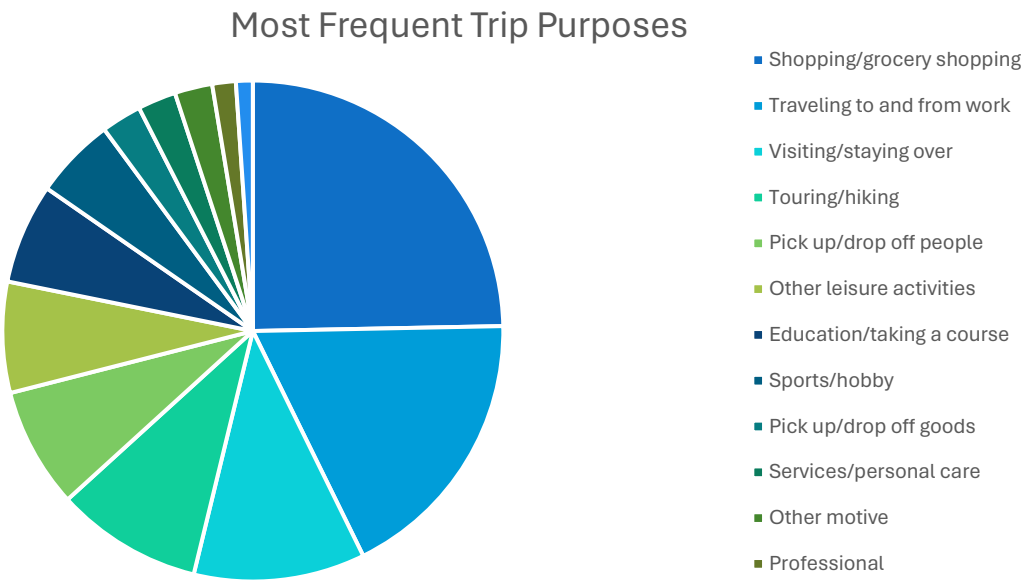


Figure 1 Most Frequent Trip Purposes

Across all records in the combined_filtered_data set the most frequent trip purposes were shopping/ grocery shopping, travelling to and from work, visiting/staying over, and touring/hiking. Other frequent purposes include picking up/ dropping off people, leisure activities, education, and sports.

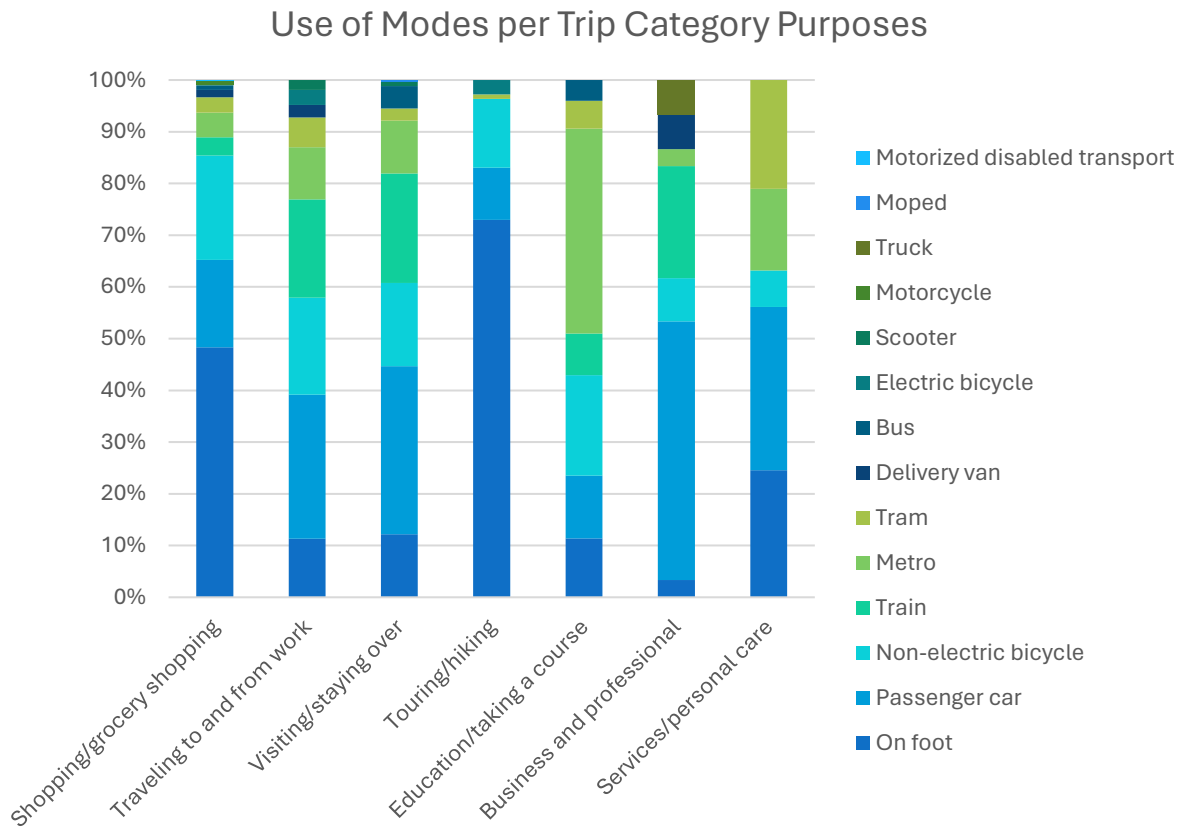


Figure 2 Use of Modes per Trip Purposes

For the most frequent trip purposes the following modes are used:
Shopping: travelling by foot, passenger car, non-electric bicycle
Work trips: passenger car, non-electric bicycle. train
Visiting/ staying over: passenger car, non-electric bicycle, train
Touring/hiking: travelling by foot, passenger car, non-electric bicycle.

Additionally, for education trips metro is used most frequently and for business trips cars and trains are used most often. For services and personal care walking, driving a car, taking a metro or tram are most frequent.

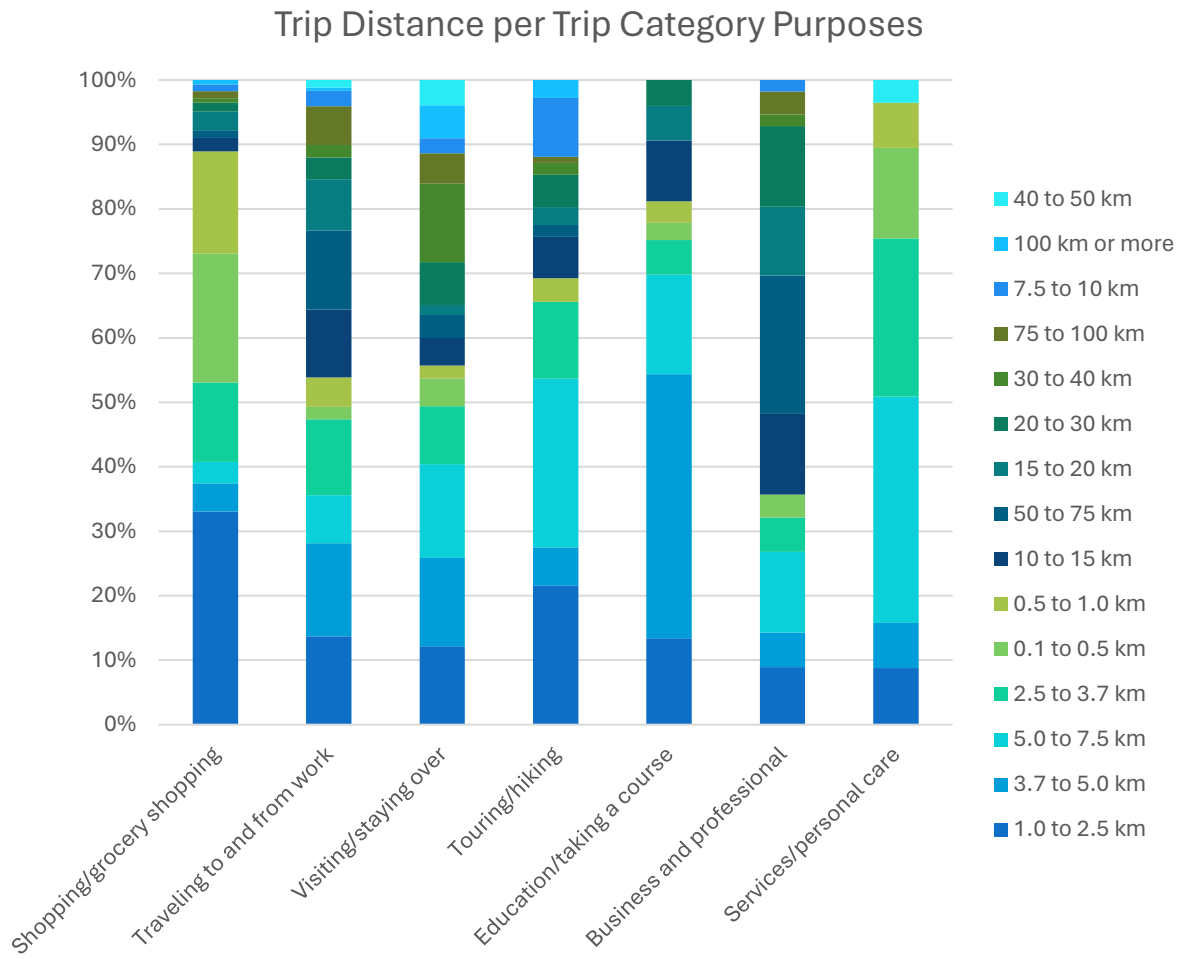


Figure 3 Trip Distance per Purpose

For shopping trips mostly short distances are covered (0.1-2.5km). For work trips there is a big dispersion in distances with most occurrences for 1 -2.5km, 2.5- 3.7km, 3.7- 5km, 10-15km, and 50- 75km travelled. Visiting/staying over trips cover short distances from 1-7.5, 10-15km trips or long-distance trips between 50-75km. Touring/hiking trips mostly cover distances of 1-2.5km or 5-7.5km.

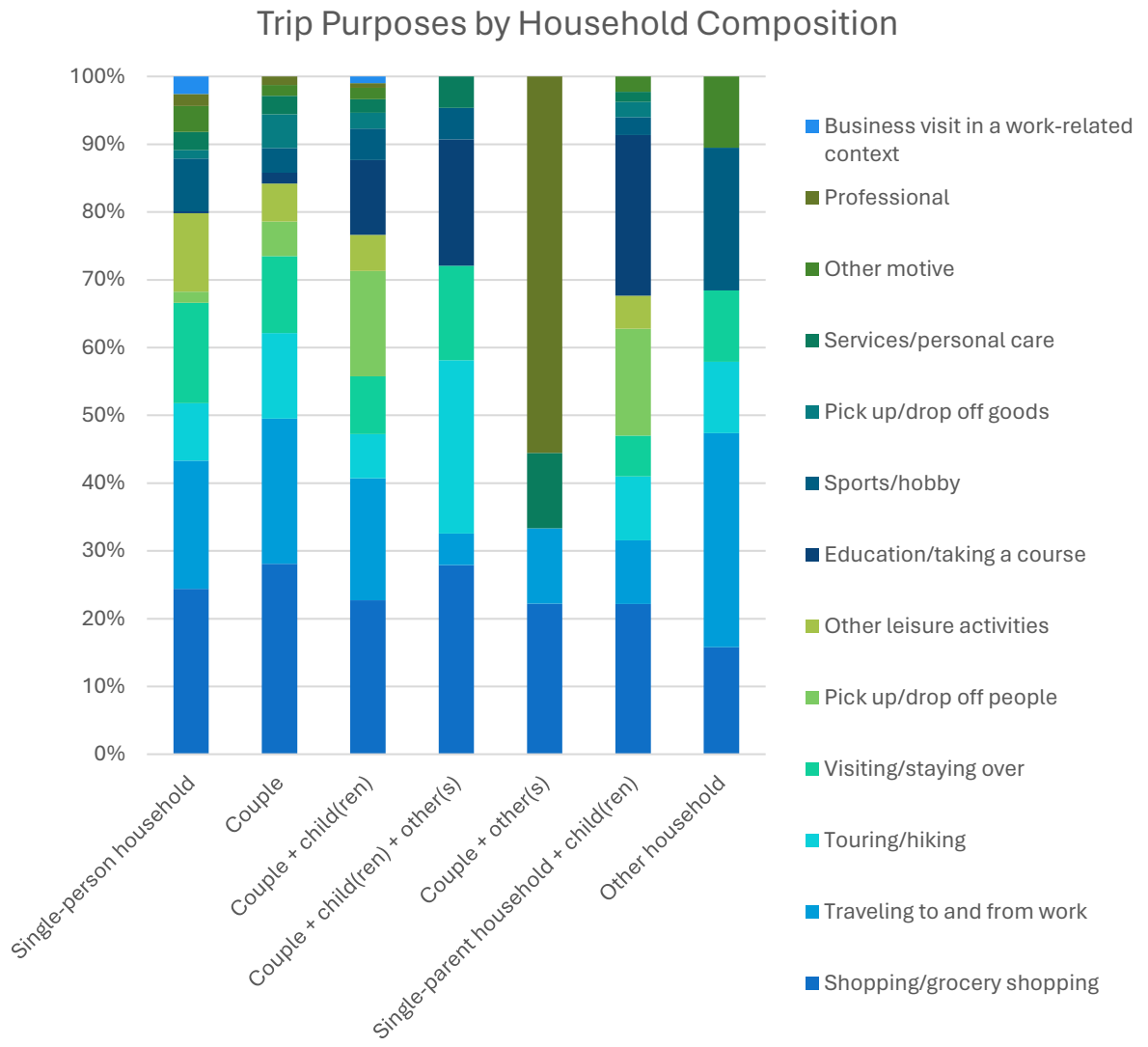


Figure 4 Trip Purpose by Household Composition

Trip purposes vary slightly per different household types. For example, picking up/ dropping off people occurs more frequently for households with children. This could be due to parents or caregivers dropping them off and picking them up from school.
For households with couple+ children + others touring and hiking trips are especially more frequent compared to others. In the same households work trips are especially rare.
For household where a couple + others live professional trips are especially frequent.
Finally, single-parent households with children seem to have a high frequency of education trips.

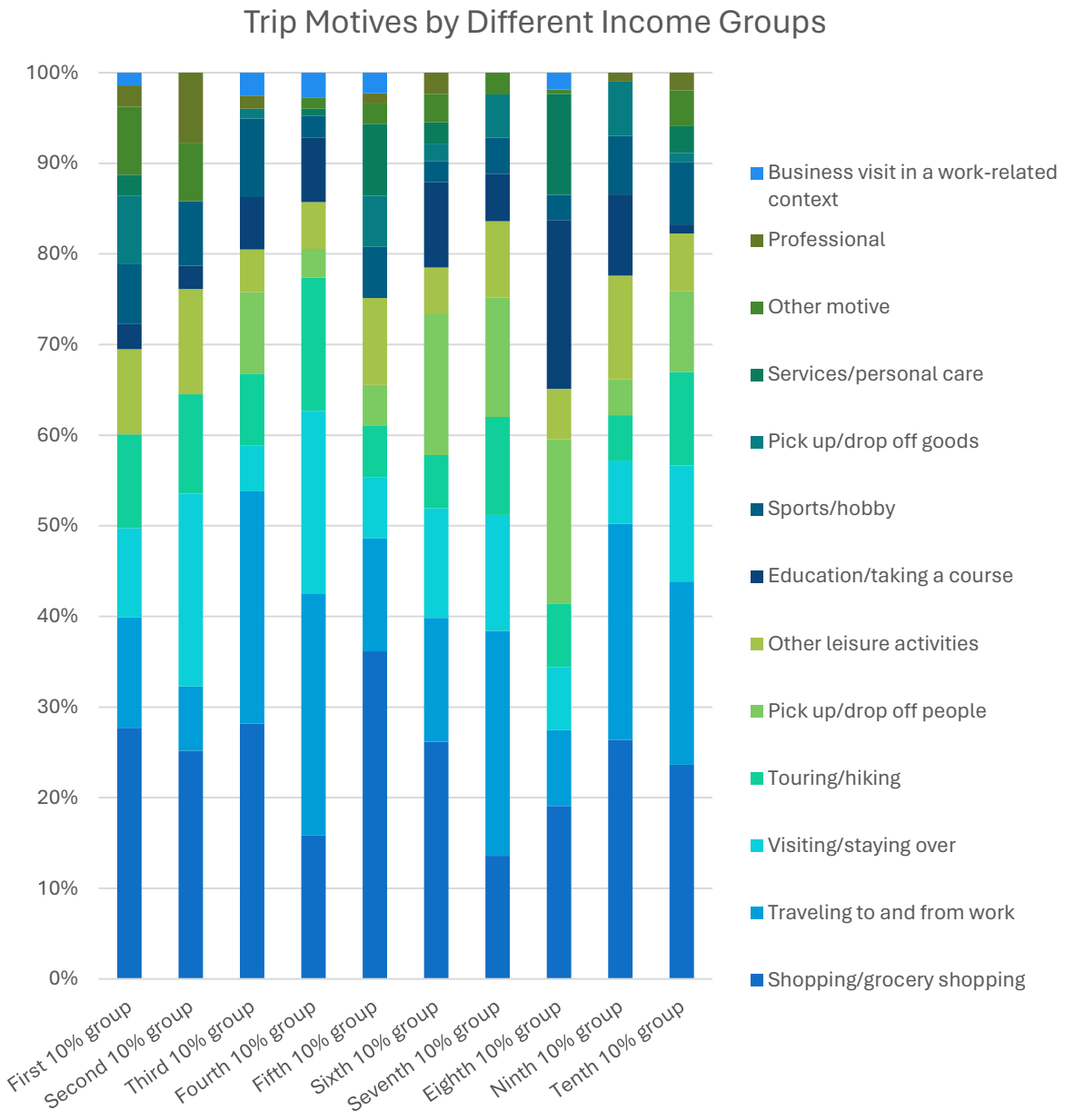


Figure 5 Trip Motives by Different Income Groups

In the graph above various income groups are represented. First 10% group represents low income households, Tenth 10% group represents high income households.
Individuals from households with income of first and second 10% groups perform significantly less work trips. Individuals from third, fourth, nineth, and tenth 10% groups perform comparably higher amount of work trips. Visiting and staying over is especially frequent for the second 10% group. Touring/hiking is slightly more frequent for the first, second, third and fourth 10% groups. Education/taking a course is exceptionally frequent for the eighth 10% group.

3. Destination

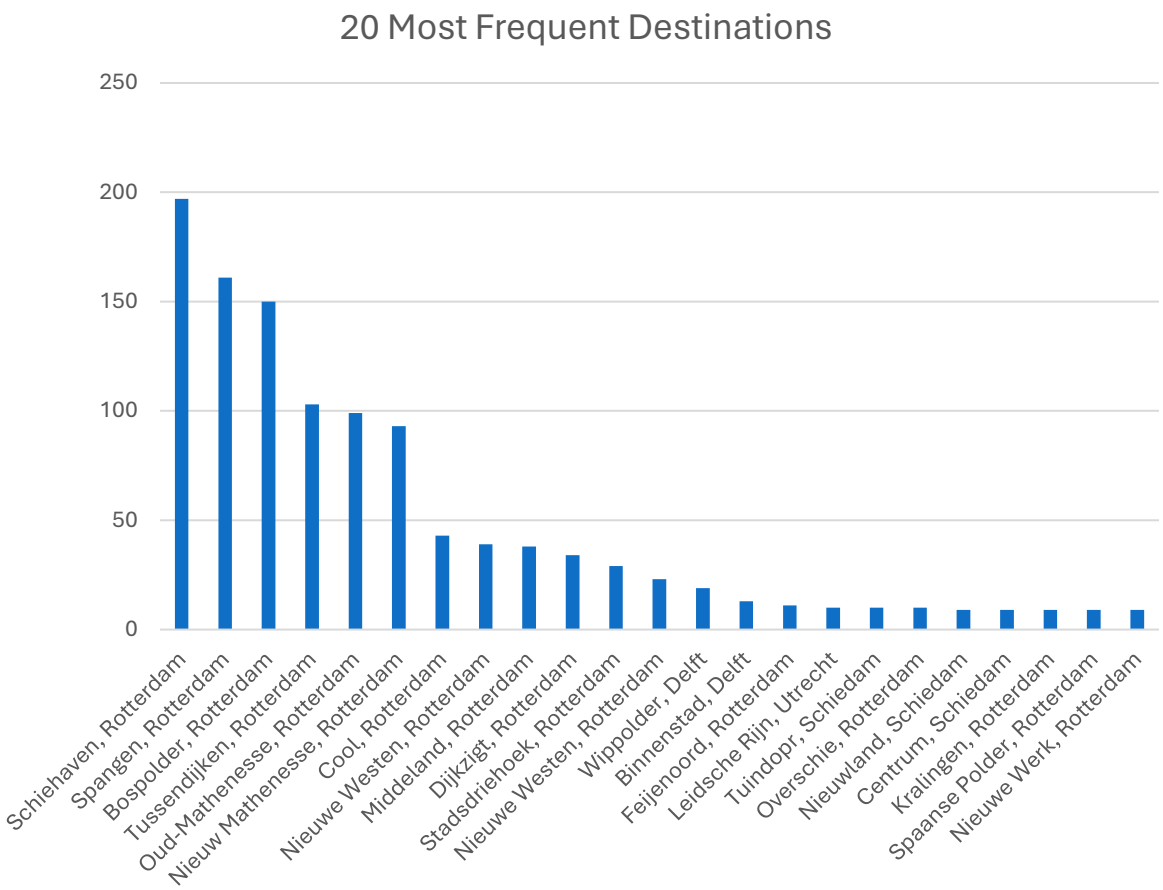


Figure 6 Twenty Most Frequent Destinations

Among all trips starting in the analyzed neighborhoods most end in the same neighborhood, a neighboring area or in an area towards the city center of Rotterdam. There are also trips to Delft, Schiedam, or Utrecht.
The 10 most frequent destinations are Schiehaven, Spangen, Tussendijken, Oud-Mathenesse, Nieuw Mathenesse, Cool, Nieuwe Westen, Middeland, and Dijkzigt in Rotterdam.

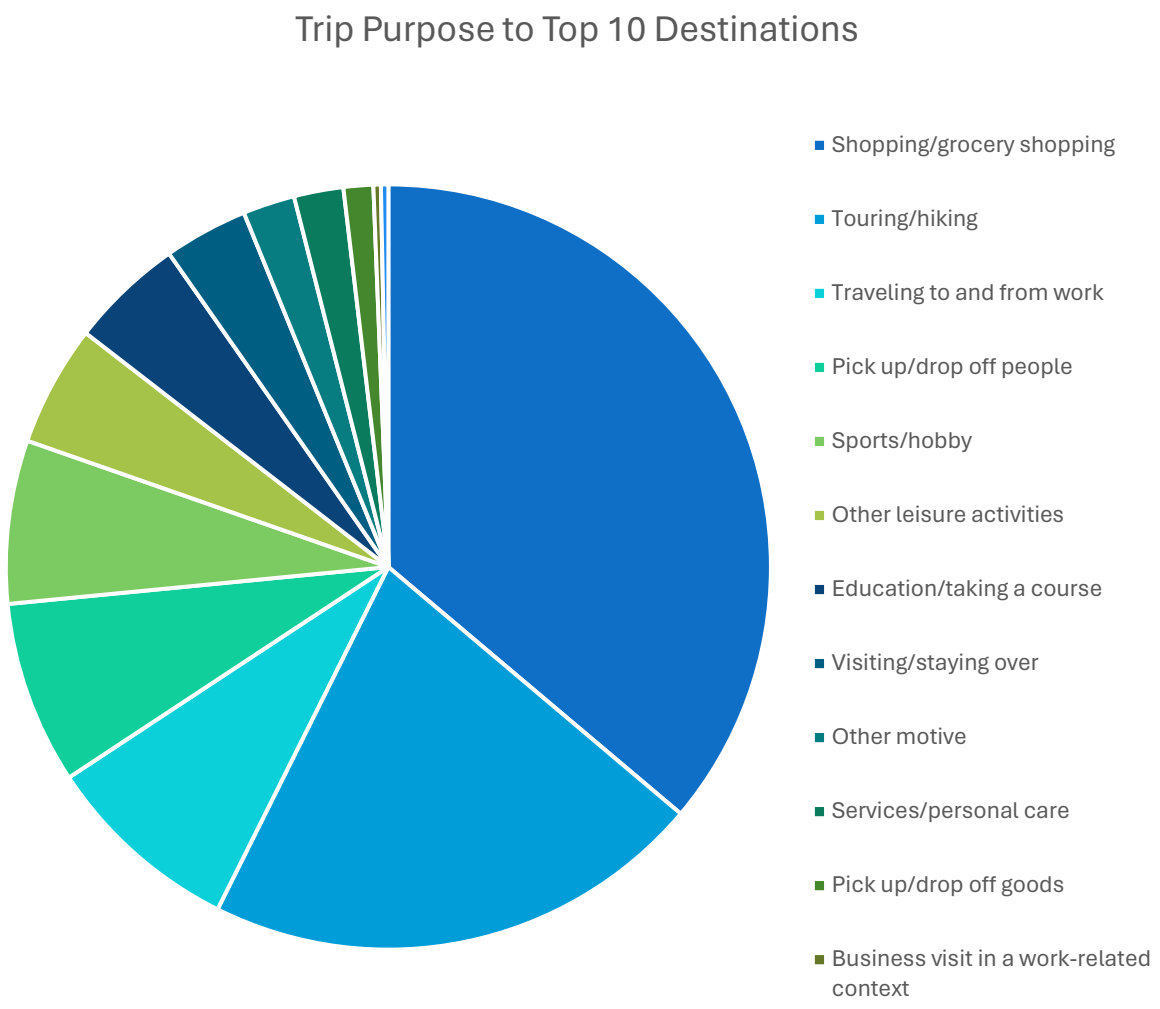


Figure 7 Trip Purposes to Top 10 Destinations

The purposes of trips to the most occurring destinations are shopping, touring/hiking, work trips, picking up and dropping off people, and doing sports/hobby.

Figure 8 Ten Most Frequent Destinations for Shopping Trips

The most frequent destinations for Shopping are in the area of Schiehaven, Bospolder and Spangen. The high frequency of trips to the area of Schiehaven could occur because of the shopping area under Dakpark where a couple of different retailers are including a grocery store and other house goods stores. Similarly, for Bospolder and Spangen which share the Schiedamseweg which is a shopping street.

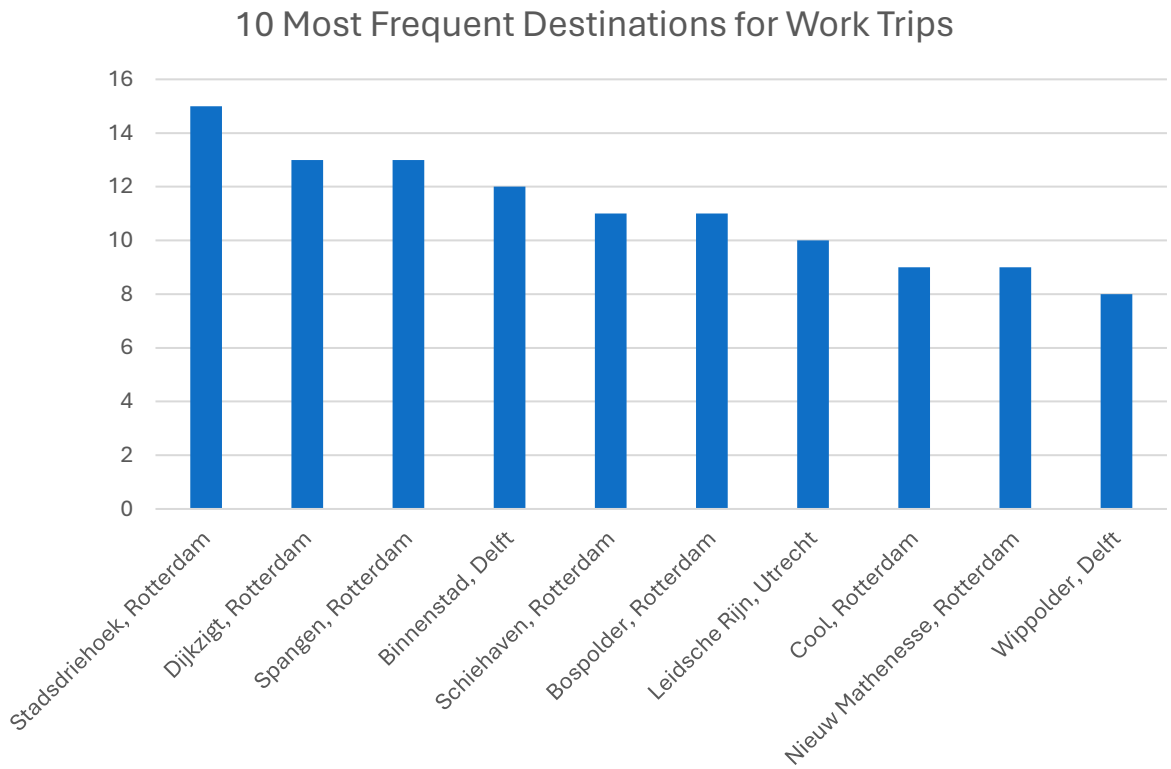


Figure 9 Ten Most Frequent Destinations for Work Trips

Some of the most frequent destinations for work-related trips are the city center of Rotterdam, the area around Erasmus MC, or the direct neighborhoods of M4H. In addition to that, work trips are often performed to Utrecht or Delft.

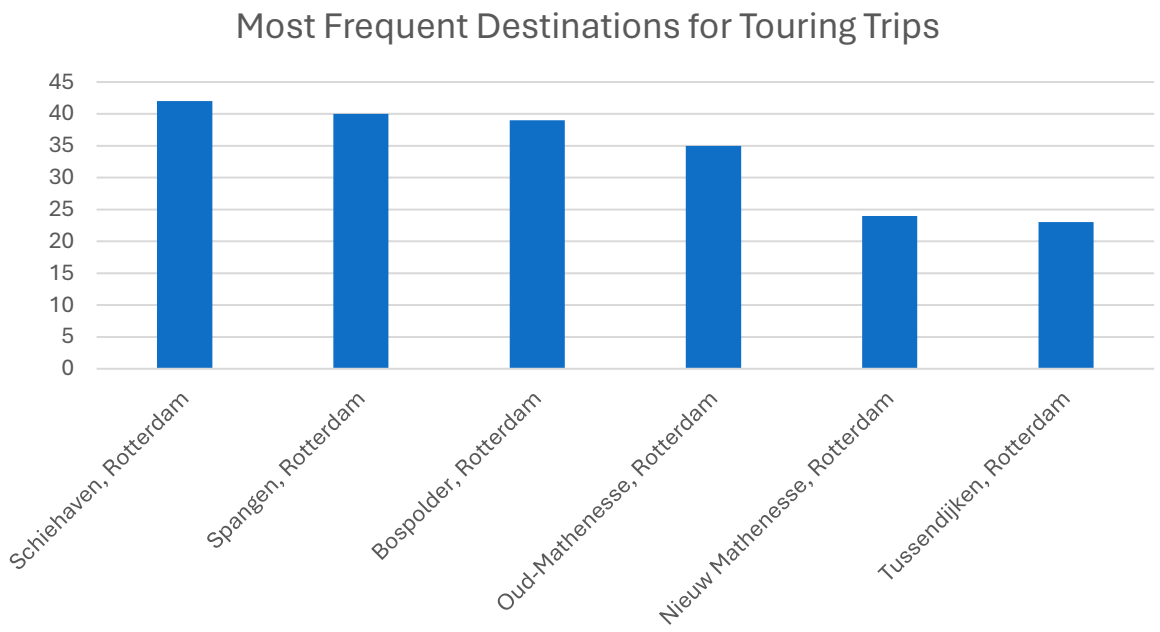


Figure 10 Most Frequent Destinations for Touring Trips

Most of the touring/hiking trips (which can be considered as taking a walk for example) take place directly in the neighborhoods of M4H.

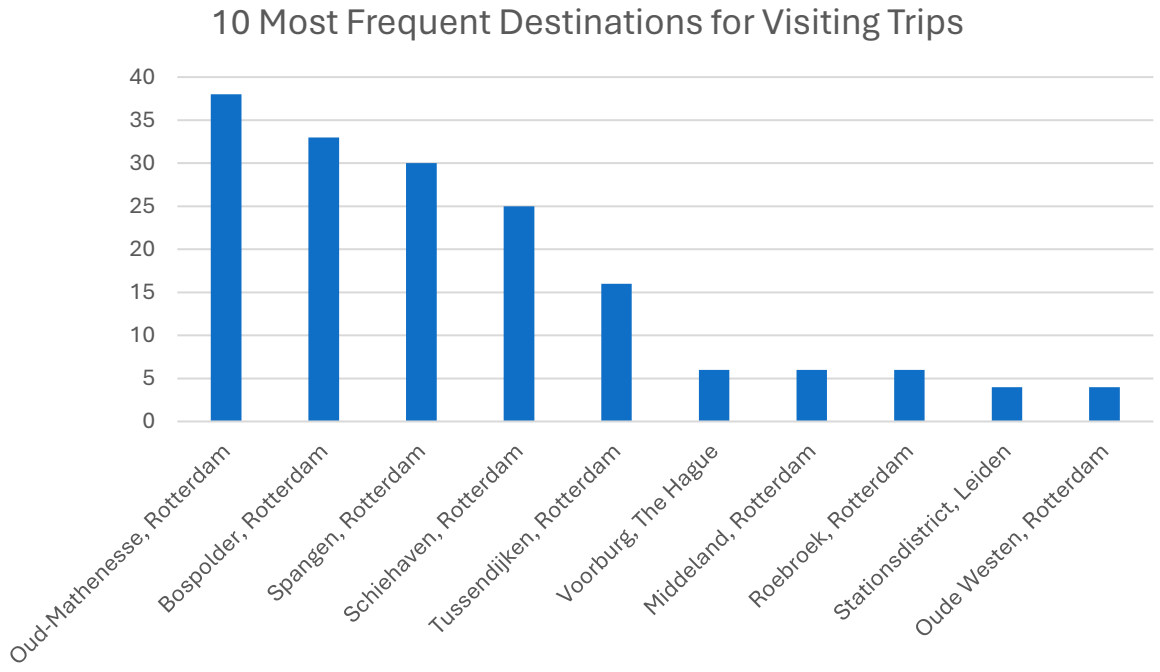


Figure 11 Ten Most Frequent Destinations for Visiting Trips

Most visiting others trips take place in the neighborhoods of M4H. However, there are also some that take place in The Hague and Leiden.

4. Mode of Transport

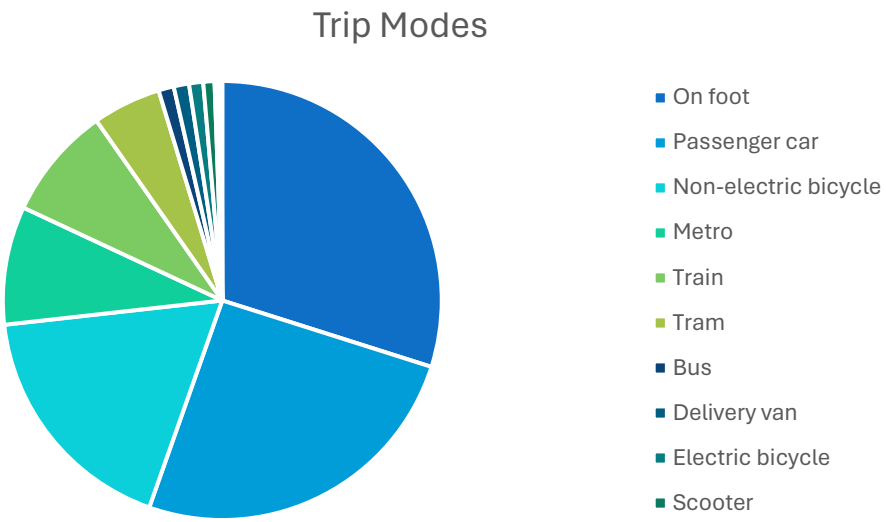


Figure 12 Trip Modes

Some of the most occurring modes for the trips people living in the M4H neighborhoods are walking, passenger car, bicycle, metro, train, tram. Other less frequent modes are bus, delivery van, electric bicycle, or a scooter.

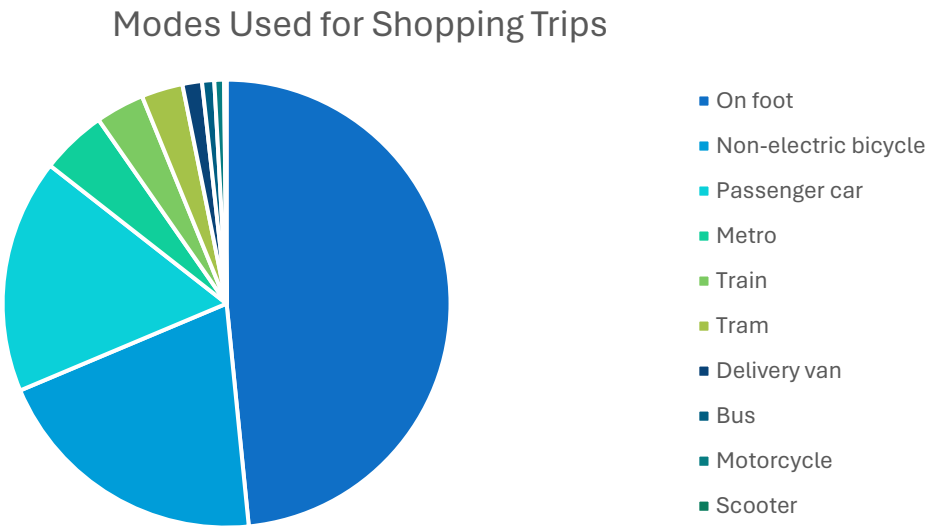


Figure 13 Modes Used for Shopping Trips

Some of the most frequently used modes for shopping trips are walking, biking, driving a car, metro, train or tram. Some less frequent modes are delivery van, bus, motorcycle, or scooter.

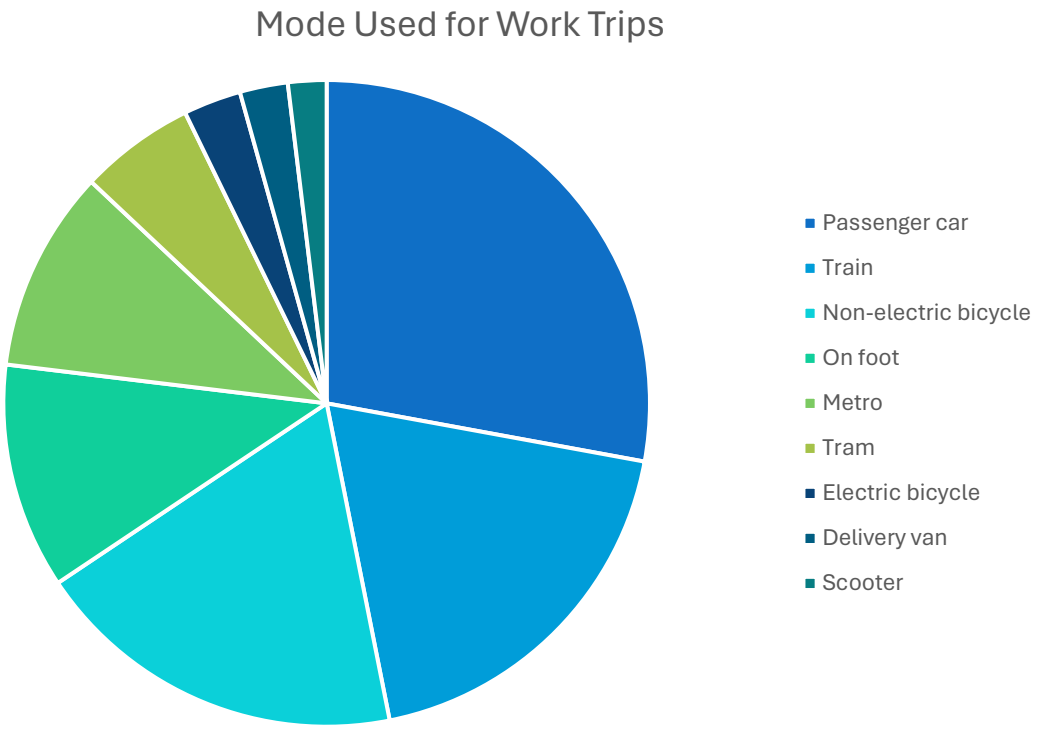


Figure 14 Modes Used for Work Trips

Some of the most frequently used modes for work trips are cars, train, bike, walking, metro, tram, electric bicycle, delivery van or scooter.

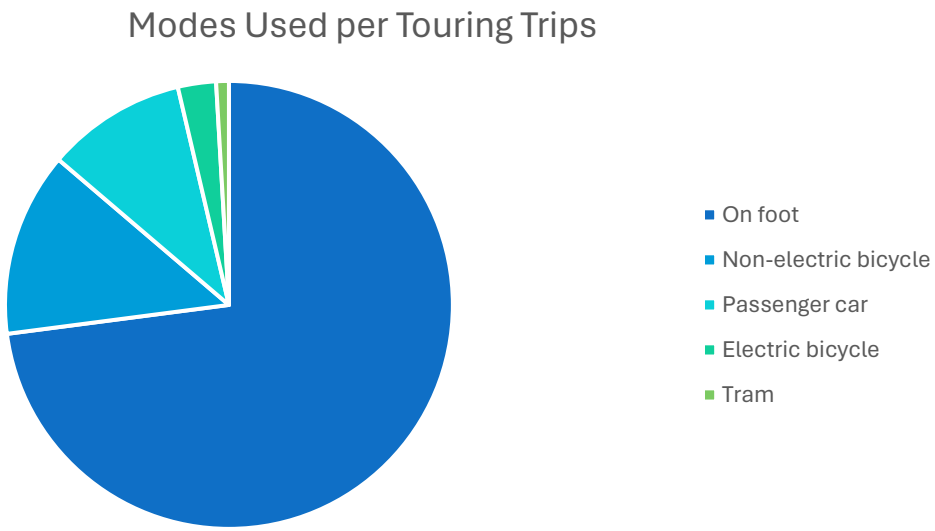


Figure 15 Modes Used for Touring Trips

Touring trips are most often done by foot, bike, car, electric bike or tram.

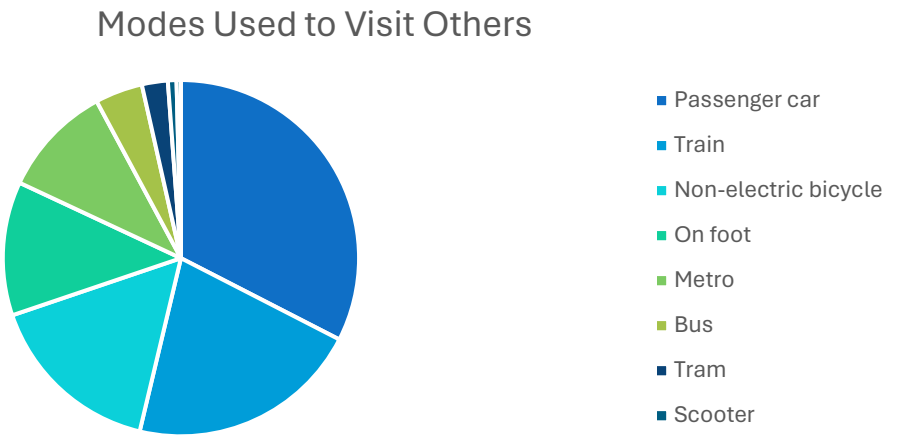


Figure 16 Modes Used to Visit Others

Visiting others most often happens by car, train, bike,on foot or by metro. Some other modes for visiting also include bus, tram, scooter.

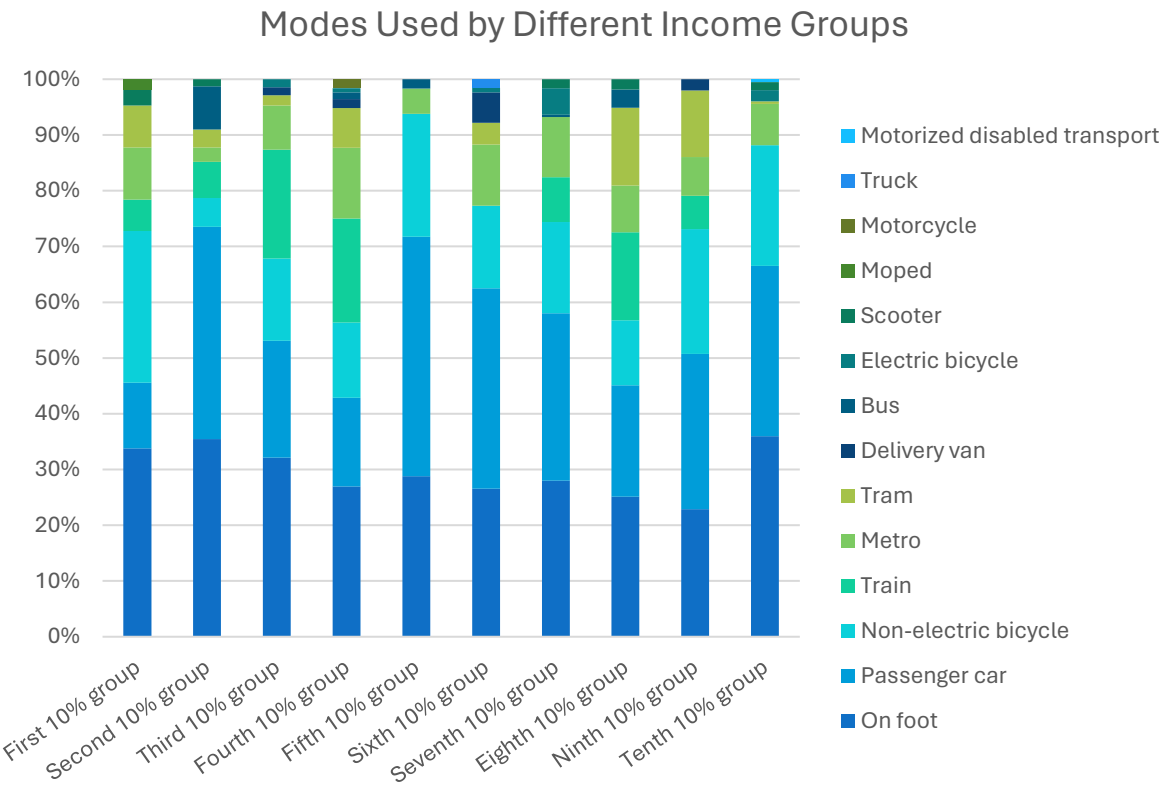


Figure 17 Modes Used by Different Income Groups

Among all income groups walking seems to be relatively equally distributed with around 30% of trips taking place by foot. However, an interesting observation for the first two 10% groups takes place where in the ffirst 10% group the second most frequent mode is biking, in the second 10% group the second most frequent mode is a car.

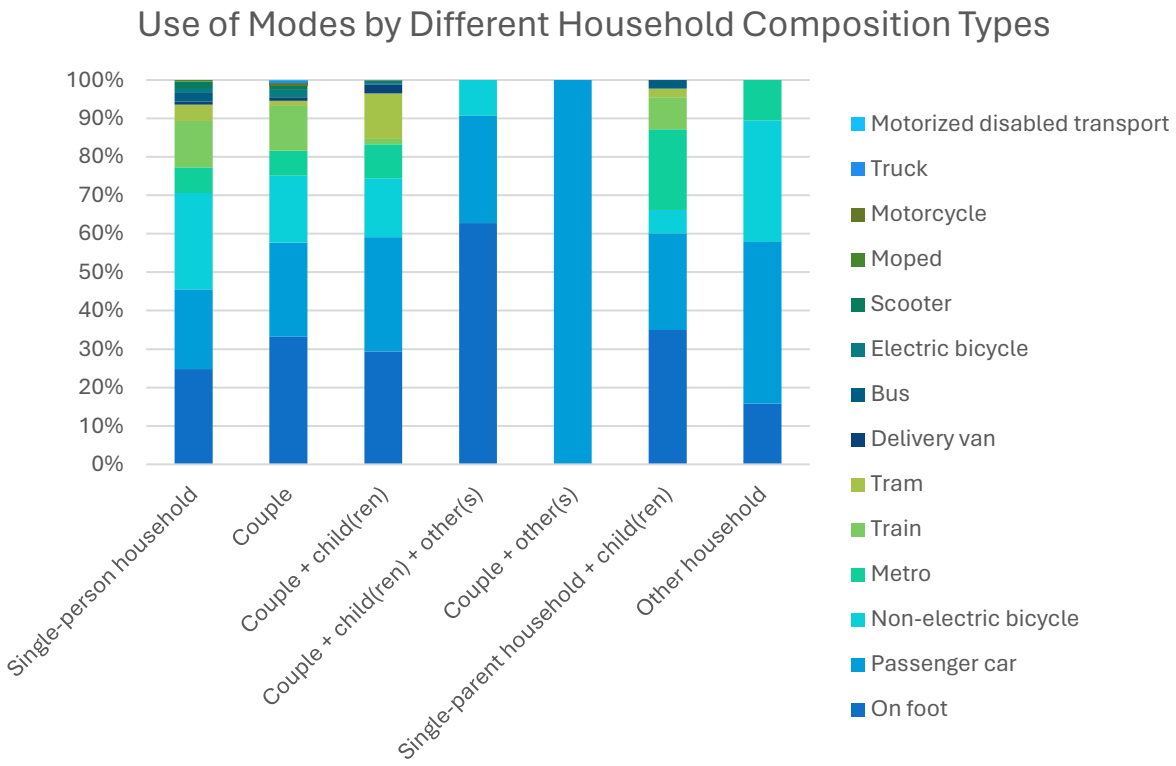


Figure 18 Use of Modes by Different Household Composition Types

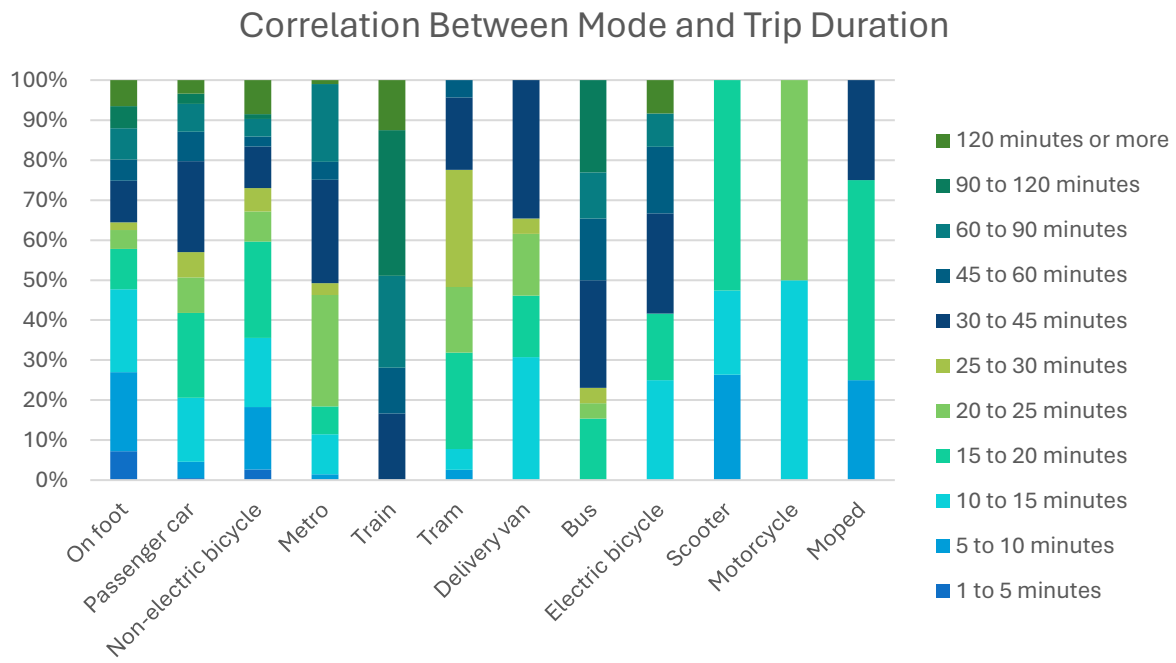


Figure 19 Correlation Between Mode and Trip Duration

Most trips on foot do not take longer than up to 20 minutes. Car trips mostly last 10 to 20 minutes or 30 to 45 minutes. Bicycle trip durations vary but most of them do not take longer than up to 20 minutes. Public transport trips usually start at 15 or 20 minutes per trip and last longer.

5. Distance

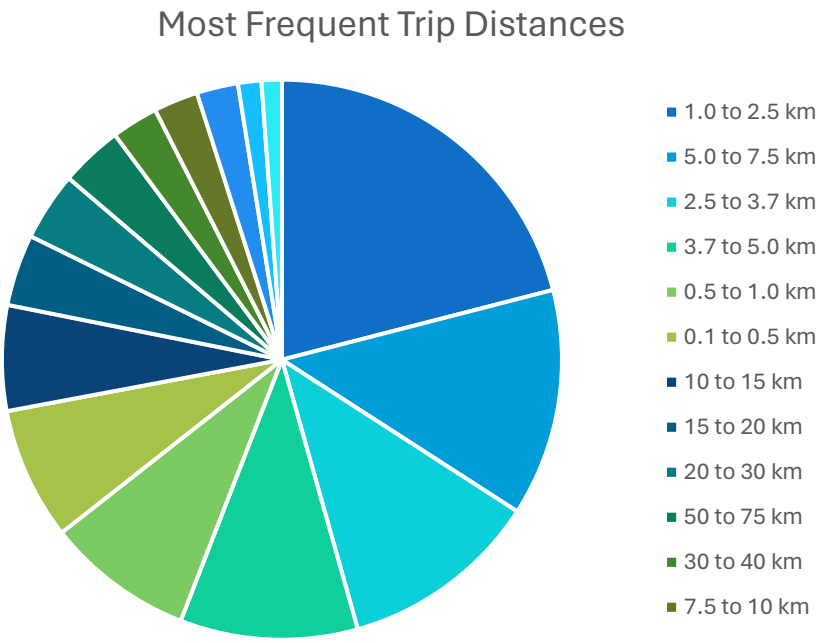


Figure 20 Most Frequent Trip Distances

Most trips do not exceed 7.5 kilometers and most trips are very short distance between 1-2.5km.

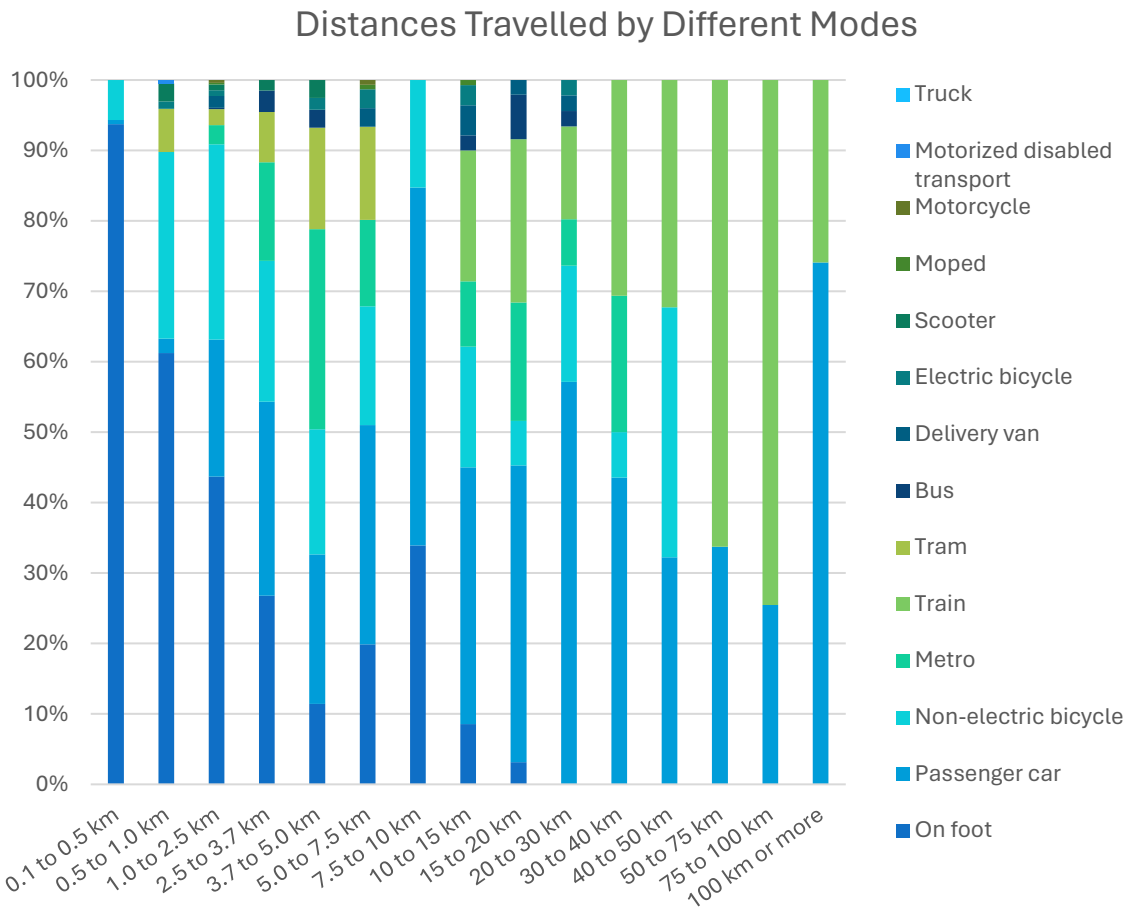


Figure 21 Distances Travelled by Different Modes

Most short distance trips are covered by foot or non-electric bike. The farther the trip the more frequent the use of cars and trains. Cars are also frequently used even for shorter trips such as 1-2.5km. They have a big share for trips from 7.5-10km and for trips over 100km cars are the most frequently used mode followed by trains. Metro and trams are often used for trips between 3.7 – 7.5km.

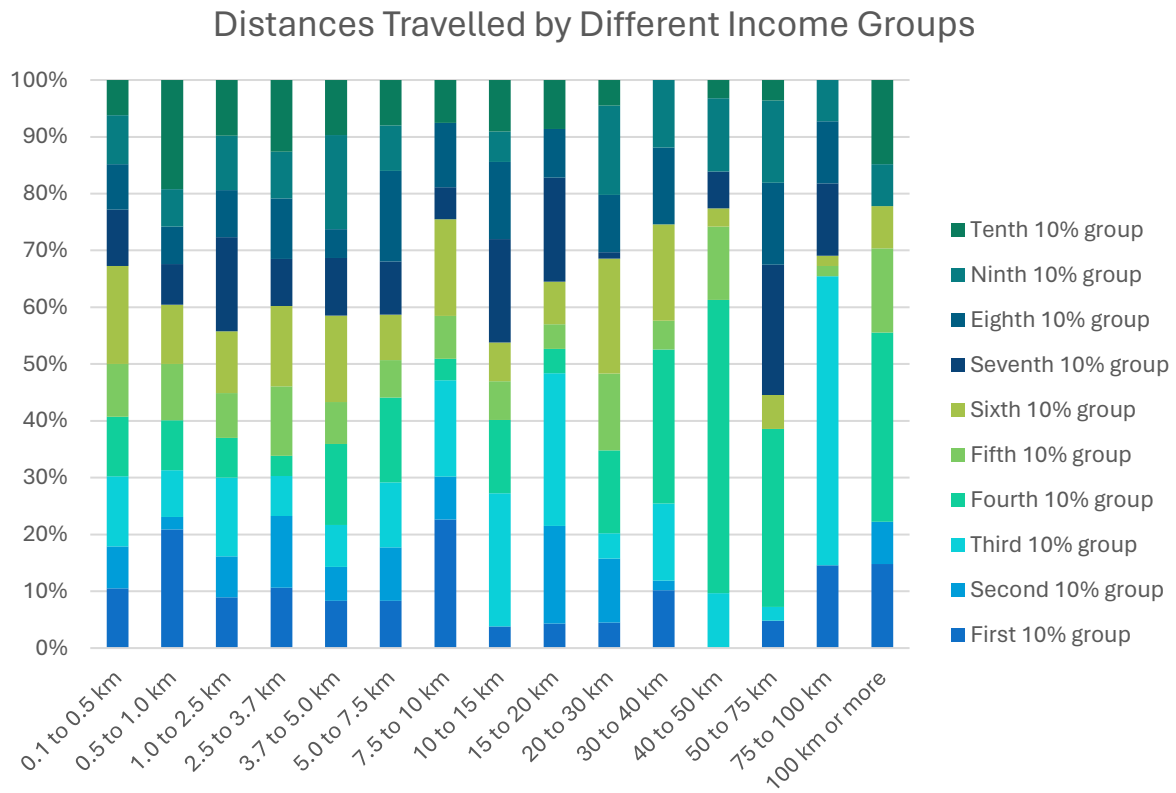


Figure 22 Distances Travelled by Different Income Groups

The correlation between distances and income groups stays varied for shorter distances (up to 10km). For trips over 10km lower and mid-range income groups travel farther distances. Especially third and fourth 10% income group.

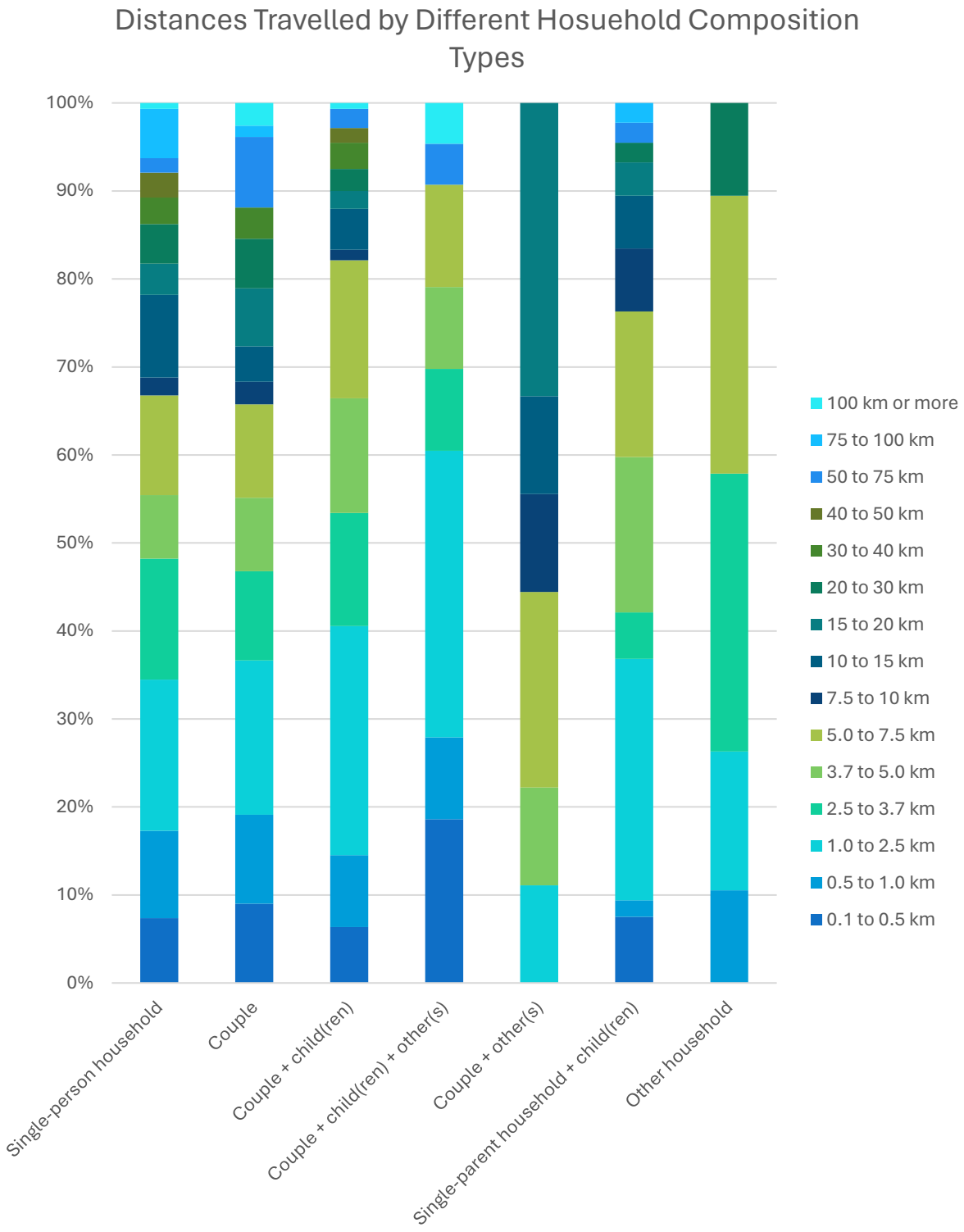


Figure 23 Distances Travelled by Different Household Types

Single- person households, couple households, and couple + children households have similar travel distance patterns. Most trips stay under 7.5 km and most frequent ones are between 1-2.5km. For households with couple + children + others there is also a higher frequency of very short trips of up to 0.5km, most trips stay under 7.5km and trips between 1-2.5km are also most frequent. However, for this group there is not a big share and differences of trips over 7.5km. Couple + others is the type of household that covers the highest travel distances with 15-20km trips being most frequent.

6. Duration

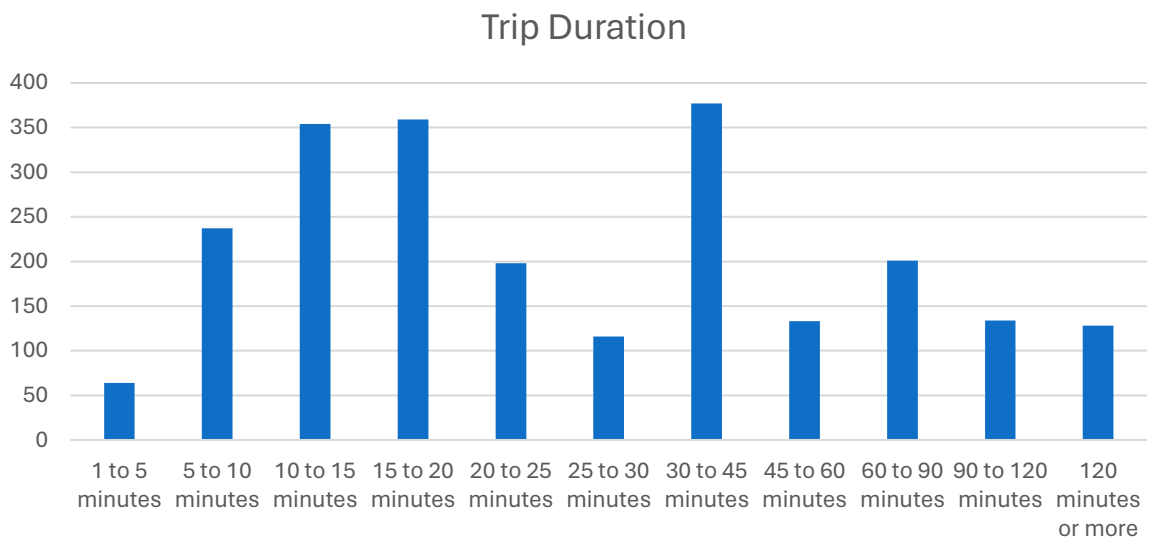


Figure 24 Trip Duration

Most trips last between 30-45 minutes, followed by 15-20 minutes and 10-15 minutes.

7. Travelling Times

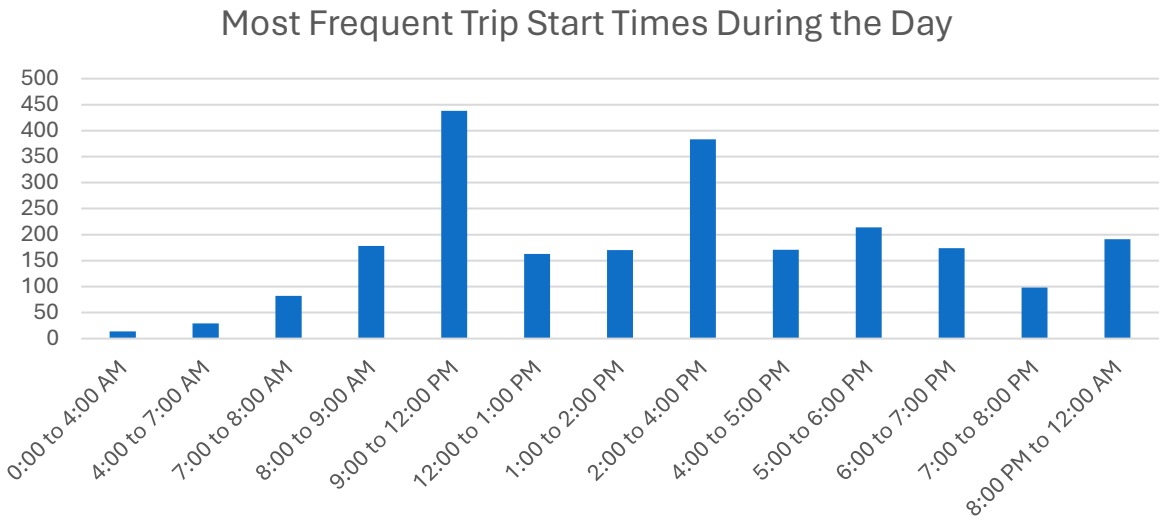


Figure 25 Most Frequent Trip Start Times During the Day

The most busy times of the day during which most trips occur are between 8:00- 9:00 AM, 9:00 to 12:00 PM, 2:00 to 4:00 PM, 5:00 – 6:00 PM, 6:00 -7:00 PM and 8:00 PM – 12:00 AM.

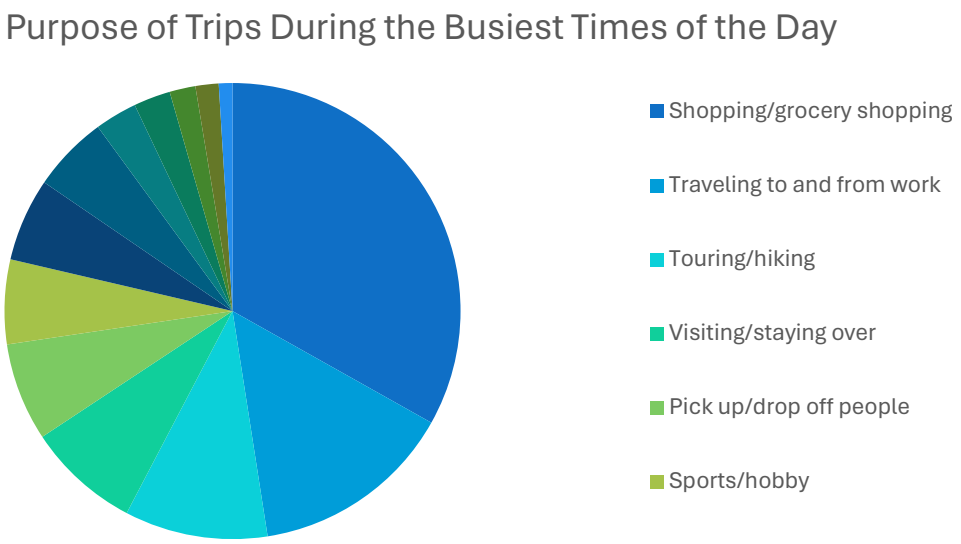


Figure 26 Purpose of Trips During the Busiest Times of the Day

The trip purposes occurring during the busiest times of the day are shopping, travelling to and from work, touring, visiting others, picking people up or dropping them off, doing sports or hobbies.

8. Conclusion

The analysis of trip data from neighbourhoods surrounding M4H in Rotterdam shows insightful patterns in travel behaviours and preferences. Shopping, commuting to work, visiting/staying over, and touring/hiking emerge as the most frequent trip purposes, indicating a diverse range of activities of residents in and around M4H. The mode of transport varies significantly based on trip purpose, with walking, passenger cars, bicycles, and public transportation being commonly used.

Destination-wise, most trips remain within the same neighbourhood or neighbouring areas, with occasional journeys to the city centre of Rotterdam, Delft, Schiedam, or Utrecht. Shopping trips predominantly target local areas with retail facilities, while work-related trips often extend to Rotterdam's city centre or neighbouring districts.

The analysis also shows the correlation between trip purposes, modes of transport, and household compositions. For instance, households with children exhibit a higher frequency of picking up/dropping off people, while households with couples, children and additional occupants prioritize touring and hiking trips. Households with couples and other occupants perform a lot of professional trips. Education trips have the highest share among single parent households compared to other household types.

Income levels also influence travel behaviours, for example, lower and mid-range-income households tend to engage in longer-distance trips.

Moreover, the duration and timing of trips shows distinct patterns, with most trips lasting between 30 to 45 minutes and peak travel times occurring during 9:00 -12:00 and 14:00 -16: 00, coinciding with shopping, work-related, and leisure activities.

APPENDIX D

Participant ID: .....

Research Information

Co-Designing Inclusive Future Mobility
Addressing Diversity in User Needs Through Virtual Reality-Assisted Studies

This research is conducted as part of an MSc study at TU Delft.

Researcher: Marta Nosowicz (TU Delft & Wageningen University and Research),

Contact persons:

- Yan Feng (TU Delft),
- Suzanne Hiemstra- van Mastrigt (TU Delft),

Partners: Gemeente Rotterdam, Deloitte, and MINI, part of BMW Group

1. Purpose of the Study

You are being invited to participate in a research study titled "*Co-Designing Inclusive Future Mobility: Addressing Diversity in User Needs Through Virtual Reality-Assisted Studies*". This study is a part of a master thesis. The purpose of this study is to examine the effectiveness of proposed future mobility solutions, particularly in the context of the Merwe-Vierhavens (M4H) area in Rotterdam. By engaging participants in various activities, such as questionnaires, Virtual Reality (VR) experiment and an interview, the research aims to understand the mobility needs and preferences of diverse user groups. Ultimately, the study seeks to provide guidelines for designing Community Mobility Hubs (CMH) and Urban Community Vehicles (UCVs), tailored to the needs of residents and communities in the M4H area and its surroundings. Your participation will take approximately 120 minutes including completion of the (1) "Questionnaire Before the VR Experience", (2) experiencing the VR environment, (3) "Questionnaire After the VR Experience" and (4) an interview after the VR experience.

2. Your Role

As a participant, you will be asked to truthfully answer questions listed in questionnaires and during the interview. Additionally, you will be asked to walk through the digital environment using the provided VR devices and reflect afterwards. You will enter the virtual CMH and explore its design and features. Next, you will hear about possible functions and use a shared UCV and observe how it interacts with the neighbourhood as it drives. All this will take place in a digital environment that resembles a video game. This environment is not meant to represent the actual future scenario. It is only meant to provoke thoughts, initiate feedback and be a conversation starter. Your task will be to follow the storyline provided as part of the experience and independently explore the environment within the limits of the software. This includes looking at different parts of the CMH, reading and listening to explanations of various features, and clicking on buttons such as 'move to next room' as instructed during the experiment.

Please note that some users may experience headaches, tiredness, eyestrain, disorientation, dizziness, nausea and increased muscle fatigue. If any of those occur during the experiment, please make sure to inform about it. You have the right to take breaks or withdraw at any time.

Please note that during the study all face-to-face encounters and the use of devices will adhere to health guidelines and safety protocols.

Participant ID: .....

3. Data Collection and Usage

I will collect your personal information such as age, gender, occupation, migration background, income level, household composition. You have the right to choose not to disclose this information. In addition to that I will also anonymously record your behaviour in the VR environment (timestamps of movements, gaze). All data will be collected through questionnaires, one interview, and the VR experiment. Answers to questionnaires will be collected digitally through the Qualtrics platform on tablets provided by the researcher, the interviews will be recorded on two devices and transcribed. All data will be collected anonymously.

Please be informed that the parties involved in this project are Gemeente Rotterdam (project host), Deloitte (organization providing the VR experience), MINI, part of BMW Group (organization providing the VR experience), TU Delft (Mobility in Extended Reality Lab, Seamless Personal Mobility Lab) and Wageningen University of Research where the researcher is a student.

The anonymous data will only be accessible to the researcher and the TU Delft and Gemeente Rotterdam supervisors. Deloitte and MINI (part of BMW Group) will only have access to anonymous records about your VR experience (a heatmap of your movements and gaze) and the publicly available results (not raw collected data) of the research.

As this research is performed for educational purposes all results, but not raw collected data, will be publicly available in the TU Delft Educational Repository at the end of the research.

Additionally, during the study material such as video recordings and photos will be taken for communication, further analysis and documentation purposes.

4. Rights and Remuneration

You have the right to refuse to answer or withdraw from the study at any time. If later you decide to withdraw your data, please contact the Researcher (contact details below).

There is no remuneration for time or compensation for travel associated with this study.

5. Contact Information

If you have any questions or concerns about the study, you may contact the Researcher, Marta Nosowicz, at m.a.nosowicz@student.tudelft.nl or marta.nosowicz@wur.nl

Participant ID: .....

Informed Consent Document

I acknowledge that I received sufficient information and explanation about the research and that all my questions have been answered satisfactorily and that participation in this research is voluntary.

I am aware that this research consists of the following activities:

1. Filling in a questionnaire before the Virtual Reality experiment.
2. Participating in the Virtual Reality experiment
3. Filling in a questionnaire after the Virtual Reality experiment.
4. Participating in an interview after the Virtual Reality experiment.

I am aware about anonymous data that will be collected during the research, such as, photos, video and audio recordings, personal information (through questionnaires and the interview), and physical movements (through the VR experiment). I give permission for collecting this data. The anonymous data will be accessible to the researcher and her TU Delft and Gemeente Rotterdam supervisors.

I give permission for using photos and/or video recordings of my participation:
(select what applies for you):

- o in which I am recognisable in publications and presentations about the project.
- o in which I am not recognisable in publications and presentations about the project.
- o for data analysis only and not for publications and presentations about the project.

I understand that result and not raw collected data of this research will be made publicly available on the TU Delft Education Repository.

I understand that Deloitte and MINI, a part of BMW Group are the providers of the VR environment. These parties will only have access to the anonymous gaze and movements data from the VR experience and the publicly available results of the research.

I acknowledge that no financial compensation will be provided for my participation in this research.

With my signature I acknowledge that I have read the provided information about the research and understand the nature of my participation. I understand that I am free to withdraw and stop participation in the research at any given time. I understand that I am not obliged to answer questions which I prefer not to answer, and I can indicate this to the research team.

I will receive a copy of this consent form.

_____ / _____ / 2024

Date (dd/mm/yyyy)

_____ _____

Participant name Signature

_____ _____

Researcher name Signature

APPENDIX E

Script for VR Experiment Sessions

Morning

Time	Activity	Description	Personnel Responsible
Pre-Session Setup (9:00 AM - 10:00 AM)			
09:00	Arrival and Room Setup	Make space for the VR experiment, leave a couple of desks for filling questionnaires and interviewing	Host/Coordinator
09:30	Device and VR Setup	Prepare the BMW file, cast to web and screen recording. Cleaning the headset after each participant.	Host/Coordinator + Technical Assistant
09:45	Form Preparation	Prepare consent forms, questionnaires and pens for each participant.	Technical Assistant
Session Start (10:00 AM)			
10:00	Welcoming Participants	Check the name on the list, hand coffee/tea	Host/Coordinator + Event Manager
10:05	Registration and Consent	Instruct on the consent form	Technical Assistant
10:10	Project Briefing	Short presentation about the project	Host/Coordinator
10:20	Pre-VR Questionnaire All participants	Hand out the pre-vr questionnaires to all participants. (ipad)	Host/Coordinator + Event Manager
VR Experience and Recording (10:40 AM - 11:20 AM)			
10:40	First VR Group (2 participants) Preparation	Hand out and instruct about the use of the VR headsets- 2 participants. Assure the VR experience boundries are separate.	Technical Assistant
10:45	First VR Group (2 participants) Experience	Record the participants experiencing the environment (casted screen).	Host/Coordinator
10:55	Post-VR Questionnaire (First Group)	Instruct the 2 participants about filling out the post-vr questionnaire. (**Make sure no dizzyness etc.).**	Host/Coordinator
10:55	Second VR Group (Next 2 participants) Preparation	Hand out and instruct about the use of the VR headsets- 2 participants. Assure the VR experience boundries are separate.	Technical Assistant
11:00	Second VR Group (2 participants) Experience	Record the participants experiencing the environment (casted screen).	Host/Coordinator
11:10	Post-VR Questionnaire (Second Group)	Instruct the 2 participants about filling out the post-vr questionnaire. (**Make sure no dizzyness etc.).**	Host/Coordinator
Group Interview and Wrap-Up (11:30 AM - 12:00 PM)			
11:30	Group Interview	Gather all participants for a debriefing discussion. Record the interview.	Host/Coordinator
12:00	Session Wrap-Up	Closing the session, inform about the availability of the results.	Host/Coordinator
12:00	Charge the VR Headsets		

Afternoon			
Time	Activity	Description	Personnel Responsible
Pre-Session Setup (2:30 PM - 3:00 PM)			
14:30	Device and VR Setup	Prepare the BMW file, cast to web and screen recording. Cleaning the headset after each participant.	Host/Coordinator + Technical Assistant
14:45	Form Preparation	Prepare consent forms, questionnaires and pens for each participant.	Technical Assistant
Session Start (3:00 PM)			
15:00	Welcoming Participants	Check the name on the list, hand out the laminated project brief,hand coffee/tea	Host/Coordinator + Event Manager
15:05	Registration and Consent	Instruct on the consent form	Technical Assistant
15:10	Project Briefing	Short presentation about the project	Host/Coordinator
15:20	Pre-VR Questionnaire All participants	Hand out the pre-vr questionnaires to all participants.	Host/Coordinator + Event Manager
VR Experience and Recording (3:40 PM - 4:35 PM)			
15:40	First VR Group (2 participants) Preparation	Hand out and instruct about the use of the VR headsets- 2 participants. Assure the VR experience boundries are separate.	Technical Assistant
15:45	First VR Group (2 participants) Experience	Record the participants experiencing the environment (casted screen).	Host/Coordinator
15:55	Post-VR Questionnaire (First Group)	Instruct the 2 participants about filling out the post-vr questionnaire. (**Make sure no dizzyness etc.).**	Host/Coordinator
15:55	Second VR Group (Next 2 participants) Preparation	Hand out and instruct about the use of the VR headsets- 2 participants. Assure the VR experience boundries are separate.	Technical Assistant
16:00	Second VR Group (2 participants) Experience	Record the participants experiencing the environment (casted screen).	Host/Coordinator
16:10	Post-VR Questionnaire (Second Group)	Instruct the 2 participants about filling out the post-vr questionnaire. (**Make sure no dizzyness etc.).**	Host/Coordinator
Group Interview and Wrap-Up (16:30 - 17:00)			
16:30	Group Interview	Gather all participants for a debriefing discussion. Record the interview.	Host/Coordinator
17:00	Session Wrap-Up	Closing the session, inform about the availability of the results.	Host/Coordinator
17:10	Closing and Room Reset	Tidy the space and return to intial setup.	All

Charge VR for next day
Make sure all data is saved correclty

Session Schedule	
Morning Session	10:00 AM - 12:00 AM
Afternoon Session	15:00 PM - 17:00 PM
Setup and Buffer	1 hour before and after each session for setup and wrap-up

Roles
Host/Coordinator
Technical Assistant
Photographer/Event Manager

Room Reservation	
1st of May	2.02
6th of May	2.01
8th of May	2.01
13th of May	2.01
15th of May	2.02

APPENDIX F

Are YOU the future city CHANGEMAKER?

Get ready to embark on an adventure that could change the way we move forever! Be a part of a research initiative that puts you at the forefront of informing the future of mobility in M4H!

We're on a mission to uncover the diverse needs and dreams of our community for future mobility solutions. By joining us, you'll have the chance to contribute valuable insights that will inform the development of inclusive and sustainable mobility in M4H!

Don't miss out on the opportunity to experience tomorrow's urban mobility scenario today! Join our research and participate in an immersive Virtual Reality experience this May to see the exciting possibilities that lie ahead.

We will organize an event here, at the heart of M4H to bring the change makers together and shape the future of tomorrow's mobility.

Interested? SCAN THE CODE to learn more and RESERVE YOUR SPOT!

SCAN HERE

Experience the future of mobility and help us understand what is important for you!

Join for FREE, meet great people and enjoy drinks and snacks!

MAY 2024

This project is a part of a master thesis research conducted by a MSc Metropolitan Analysis, Design and Engineering student.
**Participants must be able to speak English.*

Our city's transportation system has come a long way, but there are still challenges to overcome. The way we move affects our lives in many ways, from the environment to our health. That's why we're conducting research to understand how to make transportation better for everyone.

My name is Marta, and I am working on my master's thesis where I want to explore how future mobility solutions fit people like me and you. My research is all about trying to understand user needs and coming up with recommendations for planners in our city to help them create a city that works for all.

Using Virtual Reality I want to help you imagine what the future of transportation could look like and have a conversation about what could work and what not. By working together, we can help professionals understand how to create a transportation system that works for everyone.

I need your help to make this research a success! By participating in surveys, interviews, and the Virtual Reality experience, you'll be helping understand what's important to you when it comes to getting around. It will also be a great opportunity to meet creatives and inspiring people from your community, learn and together have an impact on the future.

Your voice matters, and together, we can build a transportation system that works for all of us!

See you soon in M4H?

Best,
Marta
MSc Metropolitan Analysis, Design and Engineering Student

Lab
Mobility in eXtended Reality

Seamless Personal Mobility

TU Delft

WAGENINGEN UNIVERSITY & RESEARCH

MSc MADE

Ben JIJ de toekomstige STADSVERANDERAAR?

Maak je klaar om aan een avontuur te beginnen hoe we onze manier van voortbewegen voor altijd kunnen veranderen! Word onderdeel van een onderzoeksinitiatief dat jou vooraan plaatst bij het vormgeven van de toekomst van mobiliteit in M4H!

We zijn op een missie om de diverse behoeften en dromen van onze gemeenschap te ontdekken voor toekomstige mobiliteitsoplossingen. Door deel te nemen aan ons onderzoek, krijg je de kans om waardevolle inzichten te geven voor de ontwikkeling van inclusieve en duurzame mobiliteit in M4H!

Mis de kans niet om vandaag al het stedelijke mobiliteitsscenario van morgen te ervaren! Doe mee aan ons onderzoek en neem deel aan een meeslepende Virtual Reality-ervaring in mei om uit de eerste hand de spannende mogelijkheden te zien die voor ons liggen.

We zullen een evenement organiseren in het hart van M4H, om de veranderaars samen te brengen en de toekomst van mobiliteit van morgen vorm te geven.

Geïnteresseerd? SCAN DE CODE om meer te weten te komen en RESERVEER JE PLEK!

SCAN HERE

Ontdek de toekomst van mobiliteit en help ons begrijpen wat voor u belangrijk is!

Sluit je GRATIS aan, ontmoet geweldige mensen en geniet van drankjes en snacks!

MEI 2024

Dit project maakt deel uit van een masterthesis-onderzoek uitgevoerd door een student MSc Metropolitan Analysis, Design and Engineering.
**Deelnemers moeten in staat zijn Engels te spreken.*

Ons stadsvervoerssysteem heeft een lange weg afgelegd, maar er zijn nog steeds uitdagingen te overwinnen. De manier waarop we ons verplaatsen heeft op vele manieren invloed op ons leven, van het milieu tot onze gezondheid. Daarom voeren we onderzoek uit om het vervoer voor iedereen te verbeteren.

Mijn naam is Marta, en ik werk aan mijn afstudeerproject waarin ik wil onderzoeken hoe toekomstige mobiliteitsoplossingen passen bij mensen zoals jij en ik. Mijn onderzoek draait allemaal om het begrijpen van de behoeften van gebruikers en het doen van aanbevelingen voor planners in onze stad om hen te helpen een stad te creëren die voor iedereen werkt.

Met behulp van Virtual Reality wil ik je helpen om je voor te stellen hoe de toekomst van het vervoer eruit zou kunnen zien en een gesprek voeren over wat wel en niet zou kunnen werken. Door samen te werken, kunnen we een vervoerssysteem ontwerpen dat voor iedereen werkt.

Ik heb jouw hulp nodig om dit onderzoek tot een succes te maken! Door deel te nemen aan enquêtes, interviews, en de Virtual Reality-ervaring, help je ons te begrijpen wat voor jou belangrijk is als het gaat om je verplaatsingen. Het zal ook een geweldige gelegenheid zijn om creatieve en inspirerende mensen uit jouw gemeenschap te ontmoeten, te leren en samen invloed uit te oefenen op de toekomst.

Jouw stem telt, en samen kunnen we een vervoerssysteem bouwen dat voor ons allemaal werkt!
Zien we elkaar binnenkort in M4H?

Groetjes,
Marta
MSc Metropolitan Analysis,
Design and Engineering Student

Lab
Mobility in eXtended Reality
Seamless Personal Mobility
TU Delft
WAGENINGEN UNIVERSITY & RESEARCH
MSc MADE

Are YOU the future city CHANGEMAKER?

Get ready to embark on an adventure that could change the way we move forever! Be a part of a research that puts you at the forefront of informing the future of mobility in M4H!

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We will organize an event here, at the heart of M4H to bring the change makers together and shape the future of tomorrow's mobility.

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SCAN HERE

Experience the future of mobility and help us understand what is important for you!

Join for FREE, meet great people and enjoy drinks and snacks!

MAY 2024

This project is a part of a master's thesis research conducted by a MSc Metropolitan Analysis, Design and Engineering student.
**Participants must be able to speak English.*

Lab Mobility in eXtended Reality · Seamless Personal Mobility · TU Delft · Wageningen University & Research · MSc MADE · AMS Amsterdam Institute for Advanced Metropolitan Solutions

Ben JIJ de toekomstige STADSVERANDERAAR?

Maak je klaar om aan een avontuur te beginnen hoe we onze manier van voortbewegen voor altijd kunnen veranderen! Word onderdeel van een onderzoeksinitiatief dat jou vooraan plaatst bij het vormgeven van de toekomst van mobiliteit in M4H!

We zijn op een missie om de diverse behoeften en dromen van onze gemeenschap te ontdekken voor toekomstige mobiliteitsoplossingen. Door deel te nemen aan ons onderzoek, krijg je de kans om waardevolle inzichten te geven voor de ontwikkeling van **inclusieve en duurzame mobiliteit in M4H!**

Mis de kans niet om vandaag al het stedelijke mobiliteitsscenario van morgen te ervaren! Doe mee aan ons onderzoek en neem deel aan een **meeslepende Virtual Reality-ervaring in mei** om uit de eerste hand de spannende mogelijkheden te zien die voor ons liggen.

We zullen een evenement organiseren in het hart van M4H, om de veranderaars samen te brengen en de toekomst van mobiliteit van morgen vorm te geven.

Geïnteresseerd? SCAN DE CODE om meer te weten te komen en RESERVEER JE PLEK!

SCAN HERE

Ontdek de toekomst van mobiliteit en help ons begrijpen wat voor u belangrijk is!

Sluit je GRATIS aan, ontmoet geweldige mensen en geniet van drankjes en snacks!

MEI 2024

Dit project maakt deel uit van een masterthesis-onderzoek uitgevoerd door een student MSc Metropolitan Analysis, Design and Engineering.
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Lab Mobility in eXtended Reality · Seamless Personal Mobility · TU Delft · Wageningen University & Research · MSc MADE · AMS Amsterdam Institute for Advanced Metropolitan Solutions

APPENDIX G

Participant ID: .....

Future Mobility in Virtual Reality
Pre-Experience Questionnaire

Hello!

Thank you once again for participating in this research. This is the first questionnaire I would like you to fill in. In this part the questions are focused on your demographic background and your mobility patterns, preferences, experiences and expectations. Collecting this information will help me put the results of the following parts of the research in a better context.

You will see a mix of open-ended and multiple-choice questions. Please try to be as specific as possible with your answers.

Feel free to ask any questions at any time.

Section 1: Participant Background Information

1. What is your age?
    a) Your age: _____
    b) Prefer not to say.

2. What is your gender?
    a) Male
    b) Female
    c) Non-binary
    d) Prefer not to say.

3. What is your current occupation?
    a) Your occupation: _____
    b) Prefer not to say.

4. Do you have a migrant background?
    a) No
    b) First-generation migrant
    c) Second-generation migrant
    d) Prefer not to say.

5. What is your household composition?
    a) Living alone
    b) Couple
    c) Couple with children
    d) Couple with children and others
    e) Single parent and children
    f) Living with others (e.g. housemates)
    g) Other (please specify): _____
    h) Prefer not to say.

6. How would you describe your household income level?
   a) I fall in the lower 40% bracket (up to € 32.000 - € 34.000 per year)
   b) I fall in the middle 40% bracket (between € 34.000 - € 70.000 per year)
   c) I fall in the top 20% bracket (more than € 70.000 per year)
   d) Prefer not to say.

7. Which sentence describes you best? (*Select all that apply.)*
   a) I live in M4H.
   b) I live in a neighbourhood close to M4H.
   c) I work in M4H.
   d) I work in a neighbourhood close to M4H.
   e) I visit M4H frequently.
   f) Other

8. How many times before have you experienced VR?
   a) Never
   b) 1 time
   c) 2 to 5 times
   d) More than 5 times

Section 2: Mobility Needs and Patterns

9. How often **a month** do you usually use the following modes of transport?

	Daily	Couple times a week	Once a week	Couple times a month	Once a month	Not at all
Walking	○	○	○	○	○	○
Cycling	○	○	○	○	○	○
Public transport	○	○	○	○	○	○
Shared mobility	○	○	○	○	○	○
Private car	○	○	○	○	○	○
Other (please specify)	○	○	○	○	○	○

10. How often **a week** do you usually commute for the following purposes and with what mode of transport? *(Write the main mode in the box below each activity.)*

	Daily	Couple times a week	Once a week	Not at all
Work	○	○	○	○
Shopping	○	○	○	○
Education	○	○	○	○
Sports/Hobby	○	○	○	○
Going for a stroll	○	○	○	○
Pick up/ drop off people	○	○	○	○
Visiting others	○	○	○	○
Services/ personal care	○	○	○	○

11. How much time on average do the trips with the following purposes take you?

	1-5 minutes	5-10 minutes	10-20 minutes	20-40 minutes	40-60 minutes	60-90 minutes	More than 90 minutes	Not applicable
Work	○	○	○	○	○	○	○	○
Shopping	○	○	○	○	○	○	○	○
Education	○	○	○	○	○	○	○	○
Sports/Hobby	○	○	○	○	○	○	○	○
Going for a stroll	○	○	○	○	○	○	○	○
Pick up/ drop off people	○	○	○	○	○	○	○	○
Visiting others	○	○	○	○	○	○	○	○
Services/ personal care	○	○	○	○	○	○	○	○

12. How many kilometers on average do you travel for the following purposes?

	Less than 2km	2-5km	5-7km	7-10km	10-20km	20-50km	50km and more	Not applicable
Work	○	○	○	○	○	○	○	○
Shopping	○	○	○	○	○	○	○	○
Education	○	○	○	○	○	○	○	○
Sports/hobby	○	○	○	○	○	○	○	○
Taking a walk	○	○	○	○	○	○	○	○
Pick up/drop off people	○	○	○	○	○	○	○	○
Visiting others	○	○	○	○	○	○	○	○
Services/personal care	○	○	○	○	○	○	○	○

13. In an ideal situation, what would be your preferred mode of transportation for your daily trips? *(Order the different modes where 1 is "most preferred" and 5 is "the least preferred". If you are using the "other" field, please extend the scale to 6 as "the least preferred".)*

_____ Walking
_____ Cycling
_____ Public Transport
_____ Shared Mobility
_____ Private Car
_____ Other *(please specify):* _____

14. What are the most important factors for you in choosing a mode of transport for your daily trips? *(Select **the 3 most important ones**.)*

a) Affordability
b) Travel time
c) Convenience
d) Accessibility
e) Availability
f) Reliability
g) Comfort
h) Safety
i) Ease of use
j) Travel experience
k) Environmental impact
l) Other (please explain): _____

15. Are there any barriers or challenges you face in using the current transportation options available to you? *(Select all that apply.)*

a) High costs
b) Long travel time
c) Inconvenience
d) Poor accessibility
e) Poor availability
f) Unreliability
g) Lack of comfort
h) Poor safety
i) Complexity of use
j) Poor travel experience
k) Environmental impact
l) Other (please specify)
m) I don't face any barriers or challenges.

16. Do you have a driver's license?

a) Yes
b) No

17. Do you own a car?

a) Yes
b) No

Section 3: Perceptions of Shared Mobility

18. Have you used any shared mobility services before? *(Select all that apply.)*
    a) Shared scooter
    b) Shared bike
    c) Shared cargo bike
    d) Shared car
    e) Other (please specify): _____
    f) I have never used any shared mobility.

19. If you have used shared mobility before, what features do you value the most? *(Select all that apply.)*
    a) I have never used any shared mobility, this question does not apply to me.
    b) Affordability
    c) Travel time
    d) Convenience
    e) Accessibility
    f) Availability
    g) Reliability
    h) Comfort
    i) Safety
    j) Ease of use
    k) Travel experience
    l) Environmental impact
    m) Other (please specify): _____

20. If you haven't used shared mobility before, what barriers prevent you from using these services? *(Select all that apply.)*

a) I have used shared mobility before, this question does not apply to me.
b) I do not have a driver's license.
c) High costs
d) Long travel time
e) Inconvenience
f) Poor accessibility
g) Poor availability
h) Unreliability
i) Lack of comfort
j) Poor safety
k) Complexity of use
l) Poor travel experience
m) Environmental impact
n) Other (please specify): _____

21. Under what circumstances would you consider switching to a shared mobility option for your **daily commute**? Please explain shortly.

_____

_____

_____

_____

22. What are some features you would expect from shared vehicles (e.g. cars, scooters, bikes and more)?

_____

_____

_____

_____

23. What is in your opinion still needed for the features you mentioned in question 22 to exist?

_____

_____

Section 4: Perceptions of Future Mobility in M4H

24. Based on the short introduction about future mobility solutions in M4H, what aspects of the scenario in which facilities and services are shared, there is limited parking on the street, and people make use of facilities such as Community Mobility Hubs, **are you looking forward to**?

_____

_____

_____

_____

25. Based on the short introduction about future mobility solutions in M4H, what aspects of the scenario in which facilities and services are shared, there is limited parking on the street, and people make use of facilities such as community mobility hubs **are you worried about**?

_____

_____

_____

_____

26. How likely do you think it is that you would adopt community-based and shared mobility solutions in a neighborhood like M4H (as for example a resident, a worker, or a visitor)?

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
Likeliness to adopt community-based and shared mobility solutions.	1	2	3	4	5

27. What impact (positive or negative) could community-based and shared mobility solutions in a development such as M4H have on the following aspects? *Please write a short explanation for **at least one** that you think is most relevant.*

	What impact (positive or negative) could community-based and shared mobility solutions in a development such as M4H have on the following aspects?
Affordability	
Travel time	
Convenience	
Availability	
Accessibility	
Reliability	
Comfort	
Safety	
Ease of use	
Travel experience	
Environmental impact	
Other (please specify)	

APPENDIX H

Participant ID: .....

Future Mobility in Virtual Reality Post-Experience Questionnaire

Section 1: VR Experience

1. How realistic did you perceive the virtual model to be? (*Please focus on the visual design, sounds, etc.)*

	Not realistic at all	**Slightly realistic**	**Moderately realistic**	**Very realistic**	**Extremely realistic**
How realistic did you perceive the virtual model to be?	1	2	3	4	5

2. Did you experience any discomfort during the experience? (e.g. dizziness, nausea, headache, tiredness, disorientation)

a) Yes (specify): _____

b) No

Section 2: Views on Presented Solutions

3. How have your perceptions and ideas about the future solutions changed after experiencing the features of Community Mobility Hub and Urban Community Vehicle roles in VR if at all?

_____

_____

_____

_____

4. What are the specific elements within the VR scenario that positively influenced your opinion about Community Mobility Hub and Urban Community Vehicle roles?

_____

_____

_____

_____

5. What are the specific elements within the VR scenario that negatively influenced your opinion about Community Mobility Hub and Urban Community Vehicle roles?

_____

_____

_____

_____

6. How attractive do you find the concepts presented in the VR to your current daily mobility routines and challenges?

	Extremely unattractive	Somewhat unattractive	Neither attractive nor unattractive	Somewhat attractive	Extremely attractive
How attractive do you find the concepts presented in the VR to your current daily mobility needs and challenges?	1	2	3	4	5

7. Based on the VR experience, how likely do you think are you to adopt the solutions demonstrated? Please **shortly explain why** under each of your choices.

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
Using the Multifunctional Community Mobility Hub in general.					
Using shared mobility such as bikes, scooters or cargo bikes available at the hub.					
Using the parking.					
Visiting the Cafe in a mobility hub.					
Visiting the Hairdresser in a mobility hub.					
Using the Co-working space in a mobility hub.					
Visiting the Gym in a mobility hub.					
Using the Post services in a mobility hub.					
Using the Refurbishing center in a mobility hub.					
Ride sharing with the community.					

8. How important and useful is it to integrate the following features **in a vehicle?** Please **shortly explain why** under each of your choices.

	Not at all important or useful	Slightly important or useful	Moderately important or useful	Very important or useful	Extremely important or useful
Vehicles detecting fire hazards from electric vehicles					
Vehicles providing lighting in a mobility hub					
Vehicles powering amenities in the mobility hub					
Vehicles detecting heat stress or draught and hydrating soil with harvested rainwater.					

Section 3: Feedback on Presented Solutions

9. After experiencing the VR, what impact do you think the features you saw in the scenario (facilities in the Community Mobility Hub or new Urban Community Vehicle roles) will have on the following aspects of travelling? (Briefly **explain why** in the boxes below selected aspects. Select all that apply.)

	Aspects of Traveling											
	Affordability	**Travel time**	**Convenience**	**Accessibility**	**Availability**	**Reliability**	**Comfort**	**Safety**	**Ease of use**	**Travel experience**	**Environmental impact**	**Other**
Using the Multifunctional Community Mobility Hub in general.												
Using shared mobility such as bikes, scooters or cargo bikes available at the hub.												
Visiting the cafe in a mobility hub												
Visiting the hairdresser in a mobility hub												
Using the co-working space in a mobility hub												
Visiting the gym in a mobility hub												
Using the post services in a mobility hub												
Using the refurbishing centre in a mobility hub												
Ride sharing with the community												

10. After experiencing VR, which of the following aspects of travelling **could be influenced negatively** by solutions such as Community Mobility Hubs or additional roles of Urban Community Vehicles? *(Please select all that apply.)*

a) Affordability
b) Travel time
c) Convenience
d) Accessibility
e) Availability
f) Reliability
g) Comfort
h) Safety
i) Ease of use
j) Travel experience
k) Environmental impact
l) Other (please explain): _____

11. What are some features or elements you would you like to **add** to the Community Mobility Hub or future Urban Community Vehicles? Why?

_____

_____

_____

_____

12. What are some features or elements you would like to be **removed or modified** in the Community Mobility Hub or future Urban Community Vehicles? Why?

_____

_____

_____

_____

13. After experiencing VR, what do you think could make people more interested and willing to use shared mobility?

_____

_____

14. What do you think is the role of brands (e.g. in the scenario you saw BMW branding) in shared mobility scenarios?

_____

_____

APPENDIX I

Interview Guide

1. Initial Reactions and Emotional Impact

1. How would you describe your thoughts and feelings when you were experiencing the VR simulation?
2. How did the VR experience make you feel about the future of mobility in the M4H area?

2. Specific Features and Elements

3. Which aspects of the scenario did you find the most interesting? And why?
4. In the scenario you heard how vehicles can help solve urban challenges. How else you think a [shared] vehicle could be a solution in the urban environment?
5. What are additional features vehicles could have to suit not only the environment but also diverse people's travel needs?
6. If you could add or change something in the scenario to better reflect your vision of the Community Mobility Hub and operating in it vehicles, what would it be and why?
7. Do you have any concerns about the mobility solutions proposed in the VR? What recommendations would you make to improve them?

3. Alignment and Expectations

8. How has this experience changed your outlook on the experience of shared mobility in urban environments?
9. What are your main expectations of shared vehicles?
10. What are some elements that could make people more interested in using shared mobility more? Is the technology already there?
11. How can mobility hubs be made more attractive for people to use them more?

4. Additional Feedback

12. Is there anything else about your experience that you'd like to share or any final thoughts you have on the future of mobility in M4H?

➔ What is the follow up if this project?