The multimodal mobility hub and preferred facilities: its potential for sustainable travel behavior

MASTER'S THESIS

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Preface

This thesis marks the end of my student time at the Eindhoven University of Technology. I have had incredibly fun and educational years and would do it all over again. After following a bachelor's in industrial engineering and a master's in construction management, I can confidently say that I have learned a variety of things.

In this preface, I would like to express my gratitude to several people. Firstly, I want to thank Soora Rasouli for all her help and feedback, and especially for her support throughout the past year. I am also thankful to Valeria Caiati for her always insightful advice and her indispensable help with data preparation and analysis. Thanks to Bauke de Vries for taking the time to complete the graduation committee. Finally, my appreciation goes to Eleni Charoniti for helping me gather the data, meeting with me each week, and for the enjoyable conversations we had.

To my friends and family, I just want to say that I will do my best to complain a little less, at least for a while.

As this chapter closes, a new one begins. Although I must honestly say that I am a bit sad that this part of my life has come to an end, I am also really looking forward to all the new things that the future will bring.

For now, I hope you enjoy reading this thesis!

Marise Zuurbier

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Table of Contents

Summary 7

Samenvatting 10

Abstract 13

List of Abbreviations 14

List of Tables 15

List of Figures 16

1 Introduction 17

1.1 Problem definition 17

1.2 Research questions 20

1.3 Research design 20

1.4 The practical/social and/or theoretical/scientific importance of the thesis 21

1.5 Reading guide 22

2 Literature review 23

2.1 Utility of a trip 23

2.2 The multimodal mobility hub's tangible aspects 25

2.3 Mobility-as-a-Service and Demand Responsive Transport 27

2.4 Previous mobility policies 28

2.5 Conclusion 29

3 Research design 31

3.1 Survey set-up 31

3.2 Stated choice experiment 32

3.3 Conclusion 43

4 Data collection, preparation, and sample description 45

4.1 Data collection 45

4.2 Data preparation 45

4.3 Sample characteristics 46

5 Data analysis and results 49

5.1 Method 49

5.2 Choice between private car and mobility hub: model results 51

5.3 Choice between transportation modes within the hub: model results 59

6 Discussion 67

6.1 Main findings and theoretical implications 67

6.2 Limitations 71

6.3 Future research 72

6.4 Practical implications 72

7 References 74
Appendix A. Average speed 81
Appendix B. SAS output 81
Appendix C. Nlogit commands 85
C.1 Urban mobility hub choice 85
C.2 Regional mobility hub choice 85
C.3 Transportation mode choice at urban mobility hub 86
C.4 Transportation mode choice at regional mobility hub 87
Appendix D. MNL model with interaction effects 90
Appendix E. Survey 95

Summary

Car mobility is associated with many negative externalities such as traffic congestion, accidents, and air and noise pollution. In addition, cars occupy scarce space in cities. Governments therefore try to reduce car use by changing mobility policies to stimulate a shift from (private) car-centered mobility to more environmentally friendly modes of transportation. More incentives are, however, necessary as the car is still perceived as more comfortable and convenient than alternative transportation modes. In addition, in rural areas, people rely on private cars because of poor accessibility to alternative modes. When an individual does not own a car, it can affect one's accessibility and inclusiveness in society. Therefore, a solution is necessary that facilitates both people in urban and rural areas.

This research proposes a solution in the form of the multimodal mobility hub. The multimodal mobility hub is defined as a physical place where at least three transportation modes come together and where different facilities and services are offered that contribute to the area's social and/or economic development. Consequently, this study distinguishes two types of hubs: the urban mobility hub and the regional mobility hub. In Table 1, the characteristics of each hub are summarized.

Table 1 Characteristics urban and regional hub

Urban mobility hub	**Regional mobility hub**
• Located outside of but near the central part of a city, densely populated	• Located in rural areas, not densely populated
• Shorter distances to be covered to the hub and destination	• Larger distances to be covered to the hub and destination
• Improve livability of the city	• Contributes to inclusiveness and accessibility
• Offering of various transport modes	• Offering of various transport modes
• Offering of various facilities and services	• Offering of various facilities and services

The multimodal mobility hub is an emerging concept and requires travelers to change their current travel behavior which is often difficult to establish. The hub is currently high on political agendas in the Netherlands while a lot is yet unknown about this concept, such as the potential usage of different types of hubs and preferences regarding the hub in terms of design. To attract travelers to travel via the hub while substituting their car, more research is therefore necessary. Based on this, three research questions are defined.

- **RQ1:** To what extent is the multimodal mobility hub in urban and regional areas able to substitute car use?
- **RQ2:** Does the existence of facilities and services contribute to the willingness to use the multimodal mobility hub?
- **RQ3:** What is the likelihood of each individual transportation mode to be chosen by those willing to use the hub and which factors influence this choice?

To answer the research question, a survey is developed, including a stated choice experiment targeting frequent car drivers (i.e., driving the car for at least one day per week). For the stated choice experiment, respondents got eight stated choice questions where they had to choose between traveling with their own car or via the mobility hub. Subsequently, when they chose to travel via the mobility hub, they had to indicate which transportation mode they would use to reach their destination. The stated choice data are analyzed by applying a multinomial logit and random parameter mixed logit model. In this way, preferences concerning the hub and transportation modes

are identified. Answers of 924 respondents were analyzed, of which 451 respondents for the urban mobility hub and 473 respondents for the regional mobility hub.

The results showed that the private car can be substituted by traveling via a mobility hub to a limited extent. Generally, the private car is preferred over both the urban and regional hub. Car drivers chose to substitute their car for the urban mobility hub in 30.5% of the choice situations and for the regional hub in 21.2% of the choice situations. Several factors influenced the choices.

For both the urban and regional hubs, sunny weather, having a business meeting, short(er) travel distances, and high parking fees for the private car at the destination increased the likelihood of choosing the hub over the private car. In addition, people were more inclined to choose the urban hub when the parking price at the hub was free of charge. Larger transfer time (i.e., larger hub size) and being able to shop for groceries increased the attractiveness of the regional hub.

Moreover, the existence of facilities and services contributed to the use of the multimodal mobility hub. For both hubs, it was found that the presence of a social extended reality office increases the probability of choosing the hub over the car. The availability of a supermarket, café, and gym also contributed to the preference for the regional hub. This might implicate that when individuals travel larger distances, the hub becomes more attractive when it facilitates multiple activities at the location.

Besides this, the study showed the impact of personal characteristics on the choice between the private car and the urban hub. The following characteristics increased the likelihood of car drivers choosing the urban mobility hub: people who have a middle-level education, own one car, drive the car 1-2 days per week, are passenger in the car 1-2 days per week, and own an OV-card with subscription. There were also characteristics decreasing the likelihood of car drivers choosing the urban hub: people who are 55-64 years old, have a low level education, are less than 1 day per week passenger in the car, and are familiar with the shared bike but do not use it.

Additionally, several personal characteristics positively influenced the choice for the regional hub compared to the private car. These were people who have a middle-level education, own a private car, own an OV-card with subscription, and use a shared bike. Conversely, the following characteristics negatively influenced the choice for the regional hub: people who are 55-64 years old, own two cars, and are familiar with the shared bike but do not use it.

Furthermore, four transportation modes per type of hub were included in the choice experiment to answer the third research question. The shared e-bike, shared e-scooter, and shared car were included in both hubs. The bus is the fourth alternative at the urban hub, while this was the train at the regional hub. The train is faster and often used for larger distances.

The study showed that the bus (reference level) was most likely to be chosen. After that the shared bike (although insignificant), shared car, and shared scooter were most likely to be chosen. Travel time was important for some travelers but did not significantly influence individual's mode choice. People might not be sensitive to relatively small travel time changes because of the short distances. The mode's price was only relevant for the bus and shared bike; the higher the price, the less likely people were to choose these modes. People might also be less price sensitive for the shared car and scooter used for traveling short distances. Individual characteristics also affect the between the transport modes. As expected, young people (18-34 years old) preferred shared modes over the bus, while people between 35 and 54 years old showed that they were less likely to choose shared modes compared to the bus (except for the shared scooter which is positive but insignificant). Moreover, the shared car was less likely to be chosen by people with a middle income and with an OV-card subscription.

Besides this, only one transport mode was significant at the regional hub: people were more willing to use the shared car for larger distances compared to the other modes. The study showed the importance of price for the shared scooter and car choice. The prices of these were already generally higher. Moreover, people with a low income and shared bike users were more likely to choose the shared scooter. Households with kids were most likely to choose the shared car, after which the shared bike. Lastly, people who are familiar but do not use the shared bike were least likely to choose the shared bike.

The collected data in this study offer many opportunities for further analyses. For example, data about attitudes concerning multimodality and environmental friendliness were collected but were not used in this study. The impact of these attitudes on hub and transport mode choice can be investigated. Other suggestions for further research are to investigate the willingness to pay for the mobility hub and conduct analyses on the simultaneous choice between the hub and the transport modes (instead of two consecutive choices: first the hub, after which the transport mode choice).

Finally, this study can be used as a guideline for an evidence-based design of the multimodal mobility hub. Among others, it shows the importance of the location of the hub, the available amenities, and available transportation modes. It also shows the importance of parking prices. By considering the practical implications presented in this study, strategies can be developed to maximize the effectiveness and adoption of the multimodal mobility hub, contributing to a more sustainable and efficient mobility system.

Samenvatting

Automobiliteit wordt in verband gebracht met negatieve externe effecten zoals verkeersophopingen, ongelukken en lucht- en geluidsvervuiling. Ook nemen auto's schaarse ruimte in steden in. Overheden proberen daarom het autogebruik terug te dringen door mobiliteitsbeleid te veranderen en een verschuiving te stimuleren van autogerichte mobiliteit naar milieuvriendelijke vormen van vervoer. Er zijn echter meer stimuli nodig aangezien auto's vaak als handiger en comfortabeler worden ervaren dan alternatieve vervoerswijzen. Bovendien zijn mensen op het platteland vaak afhankelijk van de auto vanwege de slechte bereikbaarheid van alternatief vervoer. Wanneer iemand geen auto bezit, kan dit de toegankelijkheid en inclusiviteit in de samenleving aantasten.

Dit onderzoek introduceert daarom een oplossing in de vorm van de multimodale mobiliteitshub. De multimodale mobiliteitshub kan gedefinieerd worden als een fysieke plek waar op zijn minst drie vervoersmiddelen samenkomen en waar verschillende faciliteiten en diensten aangeboden worden die bijdragen aan de sociale en/of economische ontwikkeling van de omgeving. Dit onderzoek maakt onderscheid tussen twee typen hubs: de stedelijke mobiliteitshub en de regionale mobiliteitshub. In Tabel 2 zijn de eigenschappen per hub weergegeven.

Tabel 2 Kenmerken stedelijke en regionale mobiliteitshub

Stedelijke mobiliteitshub	**Regionale mobiliteitshub**
• Gelegen buiten maar nabij het centrum van een stad, dichtbevolkt	• Gelegen in landelijk gebied, niet dichtbevolkt
• Kortere afstanden die afgelegd moeten worden tussen de hub en bestemming	• Grotere afstanden die afgelegd moeten worden tussen de hub en bestemming
• Verbetert leefbaarheid van de stad	• Draagt bij aan inclusiviteit en bereikbaarheid
• Aanbod van diverse vervoerswijzen	• Aanbod van diverse vervoerswijzen
• Aanbod van diverse voorzieningen en diensten	• Aanbod van diverse voorzieningen en diensten

De multimodale mobiliteitshub is een opkomend concept en reizigers moeten hun reisgedrag aanpassen wanneer ze via deze plek zouden reizen. Het is echter moeilijk om het (reis)gedrag van iemand aan te passen. De hub staat momenteel hoog op de politieke agenda in Nederland terwijl er nog veel onbekend is over het concept, zoals het potentiële gebruik van de verschillende typen hubs en ontwerpvoorkeuren. Het is daarom van belang om te onderzoeken in hoeverre en hoe reizigers via de hub willen reizen terwijl ze hun eigen auto vervangen. Drie onderzoeksvragen zijn geformuleerd gebaseerd hierop.

- RQ1: In hoeverre is de multimodale mobiliteitshub in stedelijke en regionale gebieden in staat het autogebruik te vervangen?
- RQ2: Draagt het aanbieden van faciliteiten en diensten bij aan de bereidheid om gebruik te maken van de multimodale mobiliteitshub?
- RQ3: Wat is de kans dat elk afzonderlijke vervoersmiddel wordt gekozen door degenen die bereid zijn om de hub te gebruiken en welke factoren beïnvloeden deze keuze?

Een enquête is gemaakt om de onderzoeksvragen te kunnen beantwoorden inclusief een *stated choice experiment*. De doelgroep van het onderzoek is frequente autogebruikers – mensen die op zijn minst één dag per week de auto gebruiken. In het stated choice experiment kregen de respondenten acht keuzevragen waarin ze moesten kiezen tussen reizen met hun eigen auto of via de mobiliteitshub.

Vervolgens moesten ze, als ze ervoor kozen om via de hub te reizen, aangeven welk vervoersmiddel ze zouden gebruiken om hub bestemming te bereiken. De data zijn vervolgens geanalyseerd door middel van een *mutlinomial logit model* en een *random parameter mixed logit model*. De voorkeur voor de hub of de private auto, en de voorkeuren voor een bepaald vervoersmiddelen kunnen zo geïdentificeerd worden. Uiteindelijk zijn de antwoorden van 924 respondenten geanalyseerd waarvan 451 respondenten voor de stedelijke en 473 respondenten voor de regionale mobiliteitshub.

De resultaten toonden aan dat de privéauto in beperkte mate kan worden vervangen door reizen via een mobiliteitshub. Over het algemeen heeft de privéauto de voorkeur boven zowel de stedelijke als de regionale hub. Automobilisten kozen ervoor om hun auto te vervangen door de stedelijke mobiliteitshub in 30,5% van de keuzesituaties en voor de regionale hub in 21,2% van de keuzesituaties. Verschillende factoren beïnvloedden de keuzes.

Zowel voor de stedelijke als regionale hubs resulteerden zonnig weer, een zakelijke afspraak, kortere reisafstanden en hoge parkeerkosten voor de privéauto op de bestemming in een grotere kans om voor de hub te kiezen in plaats van voor de privéauto. Bovendien waren mensen meer geneigd om voor de stedelijke hub te kiezen wanneer het parkeren bij de hub gratis was. Een langere overstaptijd (d.w.z. een grotere omvang van de hub) en de mogelijkheid om boodschappen te doen droegen bij aan de aantrekkelijkheid van de regionale hub.

Bovendien droegen de aanwezigheid van faciliteiten en diensten bij aan het gebruik van de multimodale mobiliteitshub. De aanswezigheid van een *social extended reality office* vergrootte de kans dat mensen voor beide hubs kozen. De aanwezigheid van een supermarkt, café en sportschool droegen bij aan de voorkeur voor de regionale hub. Dit zou kunnen betekenen dat wanneer mensen grotere afstanden reizen, de hub aantrekkelijker wordt wanneer het meerdere activiteiten faciliteert op de locatie.

Daarnaast toonde het onderzoek de invloed van persoonlijke kenmerken op de keuze tussen de privéauto en de stedelijke hub. De volgende kenmerken vergrootten de kans dat automobilisten de stedelijke mobiliteitshub kozen: mensen met een middelbaar opleidingsniveau, eigenaren van één auto, mensen die 1-2 dagen per week met de auto rijden, mensen die 1-2 dagen per week als passagier in de auto zitten en mensen met een OV-kaart met abonnement. Er waren ook kenmerken die de kans op het kiezen van de stedelijke hub verkleinden: mensen van 55-64 jaar oud, mensen met een laag opleidingsniveau, mensen die minder dan 1 dag per week passagier in de auto waren, en mensen die bekend waren met de gedeelde fiets maar deze niet gebruikten.

Persoonlijke kenmerken beïnvloedden ook de keuze voor de regionale hub. Mensen met een middelbaar opleidingsniveau, eigenaren van een privéauto, mensen met een OV-kaart met abonnement en gebruikers van de deelfiets zijn sneller geneigd om de regionale hub te gebruiken. Daarentegen zijn mensen van 55-64 jaar, eigenaren van twee auto's en mensen die bekend zijn met de deelfiets maar deze niet gebruiken minder geneigd via de regionale hub te reizen.

Vier vervoersmiddelen per type hub zijn opgenomen in het keuze-experiment om de derde onderzoeksvraag te beantwoorden. De deelfiets, deelscooter en deelauto zijn meegenomen voor beide hubs. De bus was het vierde alternatief bij de stedelijke hub, terwijl dit de trein was bij de regionale hub. De trein is sneller en wordt vaak gebruikt voor grotere afstanden.

Het onderzoek toonde aan dat de bus (referentieniveau) het meest waarschijnlijk werd gekozen. Daarna werden de gedeelde fiets (hoewel onbetekenend), gedeelde auto en gedeelde scooter het meest waarschijnlijk gekozen. Reistijd was belangrijk voor sommige reizigers, maar had geen significante invloed op de keuze voor het vervoersmiddel. Mensen zijn mogelijk niet gevoelig voor

relatief kleine veranderingen in reistijd vanwege de korte afstanden. De prijs van het vervoersmiddel was alleen relevant voor de bus en de gedeelde fiets; hoe hoger de prijs, hoe minder waarschijnlijk mensen deze vervoerswijzen kozen. Mensen waren mogelijk ook minder gevoelig voor de prijs van de gedeelde auto en scooter wanneer ze korte afstanden aflegden. Persoonlijke kenmerken hadden ook invloed op de keuze tussen de vervoerswijzen. Zoals verwacht gaven jongeren (18-34 jaar oud) de voorkeur aan gedeelde vervoerswijzen boven de bus, terwijl mensen tussen de 35 en 54 jaar oud minder geneigd waren om gedeelde vervoerswijzen te kiezen in vergelijking met de bus (behalve voor de deelscooter, wat positief was maar niet significant). Bovendien was de deelauto minder waarschijnlijk om te worden gekozen door mensen met een middeninkomen en met een OV-kaart abonnement.

Verder was er maar één vervoerswijze significant bij de regionale hub: mensen waren eerder geneigd om de deelauto te kiezen voor grotere afstanden in vergelijking met de andere vervoerswijzen. Het onderzoek toonde het belang aan van prijs voor de keuze van de deelscooter en auto. De prijzen van deze vervoerswijzen waren over het algemeen al wat hoger. Bovendien waren mensen met een laag inkomen en gebruikers van een deelfiets meer geneigd om de deelscooter te kiezen. Huishoudens met kinderen waren het meest geneigd om de deelauto te kiezen, gevolgd door de deelfiets. Ten slotte waren mensen die bekend waren met, maar geen gebruik maakten van de deelfiets het minst geneigd om deze te kiezen.

De verzamelde gegevens in dit onderzoek bieden vele mogelijkheden voor verdere analyses. Gegevens over attitudes ten aanzien van multimodaliteit en milieuvriendelijkheid zijn bijvoorbeeld verzameld maar werden niet gebruikt in dit onderzoek. De invloed van deze attitudes op de keuze voor de hub en vervoerswijzen kan worden onderzocht. Andere suggesties voor verder onderzoek zijn het onderzoeken van de bereidheid om te betalen voor de mobiliteitshub (*willingness to pay*) en het uitvoeren van analyses naar de gelijktijdige keuze tussen de hub en de vervoerswijzen (in plaats van twee opeenvolgende keuzes: eerst de hub en daarna de keuze voor het vervoersmiddel).

Tot slot kan dit onderzoek dienen als een richtlijn voor een op bewijs gebaseerd (*evidence-based)* ontwerp van de multimodale mobiliteitshub. Onder andere toont het onderzoek het belang aan van de locatie van de hub, de aanwezigheid van bepaalde voorzieningen en beschikbare vervoerswijzen. Ook toont het onderzoek het belang van parkeerprijzen aan. Door rekening te houden met de praktische implicaties die in dit onderzoek worden gepresenteerd, kunnen strategieën worden ontwikkeld om de effectiviteit en acceptatie van de multimodale mobiliteitshub te maximaliseren, wat bijdraagt aan een duurzaam.

Abstract

This research proposes the concept of the multimodal mobility hub as a solution for car-oriented problems in urban and regional areas. The study examines people's willingness to adopt and use urban and regional hubs. Specifically, it investigates to what extent the hubs can substitute car use, the influence of facilities and services on the willingness to use the hub, and the preferred transportation modes within the hub. A stated choice experiment is conducted among 924 frequent car drivers. Findings indicate that while private cars remain the preferred choice, factors such as weather, trip purpose, travel distance, and parking prices influence the choice of urban and regional hubs. Several personal characteristics also play a role in this choice. In addition, certain facilities within the hub influence people's willingness to use the hub. In particular, the social extended reality office space contributes to the choice for the urban and regional hub, while the supermarket, café, and gym also contribute to the regional hub preference. The study shows that the bus is most likely to be chosen at the urban hub, while this is the shared car for the regional hub. Travel time is an important determinant for mode choice in the regional hub. Other factors such as travel- and socio-demographic characteristics also influence the mode choice. This study provides valuable insights for evidence-based hub design and strategies to enhance the adoption of multimodal mobility hubs, contributing to a sustainable and efficient mobility system.

Keywords: Multimodal mobility hub, transportation mode choice, mobility hub facilities, stated choice experiment

List of Abbreviations

Table 3 List of Abbreviations

BRT	Bus Rapid Transit
DRT	Demand Responsive Transit
IIA	Independence of Irrelevant Alternatives
IID	Independently and identically distributed
MaaS	Mobility as a Service
MNL	Multinomial logit (model)
MRT	Mass Rapid Transit
MXL	Mixed logit (model)
POI	Point of Interest
P+R	Park and Ride
RQ	Research question
SC	Stated choice

List of Tables

Table 1 Characteristics urban and regional hub 7
Tabel 2 Kenmerken stedelijke en regionale mobiliteitshub 10
Table 3 List of Abbreviations 14
Table 4 Overview characteristics urban and regional hub 19
Table 5 Attributes and attribute levels for the urban and regional hub 35
Table 6 Filter criteria 45
Table 7 Socio-demographics characteristics 47
Table 8 Characteristics use and ownership of the car 48
Table 9 Familiarity with shared mobility modes 48
Table 10 Results MNL and MXL model for the choice between private car and urban hub 51
Table 11 Results MNL and MXL model for the choice between private car and regional hub 55
Table 12 Results MNL model for transportation mode choice at the urban hub 60
Table 13 Results MXL model for transportation mode choice at the urban hub 62
Table 14 Results MNL model for transportation mode choice at the regional hub 63
Table 15 Results MXL model for transportation mode choice at the regional hub 65
Table 16 MNL model with interaction effects for hub choice 90
Table 17 Results MNL model with interactions for transportation mode choice at urban hub 93
Table 18 Results MNL model with interactions for transportation mode choice at regional hub 94

List of Figures

Figure 1 Conceptual model mobility hub choice 21
Figure 2 Conceptual model transportation mode choice 21
Figure 3 Outline of the thesis 22
Figure 4 Multimodal trip 23
Figure 5 Survey structure 31
Figure 6 Overview of preference and choice measurement approaches 32
Figure 7 Stages for experimental design 34
Figure 8 Travel situations 41
Figure 9 Commands SAS 42
Figure 10 Example question urban hub 43
Figure 11 Example question regional hub 43
Figure 12 Number of respondents per block (choice between hub and car) 46
Figure 13 Number of responses per block (transportation mode choice) 46

1 Introduction

This chapter introduces the topic of this thesis by defining the problem (section 1.1), formulating the research questions (section 1.2), briefly explaining the research design (section 1.3), and addressing the practical/social and theoretical/scientific importance (section 1.4). Finally, it provides a reading guide for the following chapters of the thesis (section 1.5).

1.1 Problem definition

While cities only cover 2% of the world's surface, they contribute to more than 60% of global greenhouse gas emissions worldwide (UN, n.d.). Cars are significant contributors to these emissions, emitting 21% of the total emissions in the Netherlands (CBS, 2019). To be able to meet the Paris Agreement, to keep the global heating temperature below 2°C and preferably close to 1.5°C, the use of cars must be reduced. Currently, this number of cars is only growing (CBS, 2020; Gössling, 2020), and mainly in cities, fast growth in the number of cars is happening while space here is scarce (Gössling, 2020). In addition, most private vehicles are stationary during their lifetime, occupying considerably scarce space in urban areas (Ibrahim, 2017). Car mobility is also associated with other negative externalities such as traffic congestion, accidents, and air and noise pollution. These effects are only intensified by the increased use of private vehicles (Gonzalez et al., 2021). As a result, it appears logical that governments try to change their mobility policies to shift from (private) car-centered mobility to more environmentally friendly modes of transportation such as active transport modes (walking, cycling), public transport, and shared mobility. Examples of such policies are higher taxes (ANWB, 2023), dedicated lanes for Bus Rapid Transit (BRT), improvement of public transport and bicycle routes, and giving priority to pedestrians and cyclists in the city center (Gemeente Amsterdam, 2021). Although governments aim to realize this, more incentives are necessary. The private car is still often perceived as more comfortable, convenient, and/or faster, resulting in a high share of privately owned cars on roads (Ibrahim, 2017). Additionally, in rural areas, people rely on private cars because of poor accessibility to alternative modes (Frank et al., 2021). Not owning a car can affect one's accessibility and inclusiveness in society (J.-J. Witte et al., 2021). Therefore, a solution is necessary that facilitates a shift from private cars towards more sustainable ways of traveling for both people in urban and rural areas.

The multimodal mobility hub can provide this solution. The hub is a transportation node offering multiple transport options near city centers or rural areas (Coenegrachts et al., 2021; Frank et al., 2021). At such a mobility hub, a person can change from one transport mode to another and continue the trip (Aydin et al., 2022). Electric car-sharing and (electric) bike-sharing, as well as conventional public transport and taxis can be part of the fleet. The terms multimodal (mobility) hub, (smart) mobility hub, and hub will be used interchangeably throughout the document. Nevertheless, when using this definition of the mobility hub, the hub does not distinguish itself from a regular transportation node such as a train station where one can often find rental bikes or buses beside the train. What is meant by a mobility hub should therefore be more specific. Looking at literature and (municipal/provincial) reports, there is no unique definition for the hub, and different interpretations are used. While the core of the hub's definition is 'a node where transportation modes come together where one can transfer', some authors tried to be more specific and added that a mobility hub should also offer 'convenient infrastructure for travelers such as Wi-Fi, shelters and signage' (Frank et al., 2021, p. 1), that it also is a social economic node (OV Bureau Groningen Drenthe, 2020), that at least three transportation modes should be offered (Natuur & Milieu, 2020), that, besides the mobility function, it can also be a node for spatial development (J.-J. Witte et al., 2021), that it is a place where extra functions can be added such as parcel pick-up points or offices (Meulepas et al., 2021), or that

facilities should be offered such that the hub is a destination on itself stimulating other investments in the area (Arcadis, 2017).

Based on these additional aspects, this thesis defines a hub as a physical place where at least three transportation modes come together. In addition, the hub includes facilities and services which contribute to the area's social and/or economic development. This means that just a vending machine will not suffice as this does not stimulate economic or social development. Conversely, a supermarket at the hub creates job opportunities and offers an easily accessible place to do grocery shopping, contributing to the economic and social development of the area.

Moreover, multiple types of hubs exist. In literature, there is not yet a consensus on the types of hubs that exist, but several authors have tried to conceptualize different types. One of these articles is from Blad et al. (2022), where they distinguish three types of a hub. The authors focus on a shared mobility hub which is, in essence, similar to a multimodal mobility hub but focuses on offering shared mobility modes. The first type of hub is the residential (or neighborhood) mobility hub aiming to serve residents of a specific neighborhood. The hub is not connected to the public transport system and aims to substitute car ownership. The second type is the city mobility hub or the urban mobility hub. This hub is located in densely populated areas, usually in the city center serving residents, visitors, and commuters. The hub is, furthermore, connected to the public transport system and aims to enhance the accessibility of a city. The third hub is the regional hub. Contrary to the urban hub, this one is located in lower-density areas outside the city. This hub serves the same target group as the city hub and aims to offer alternative transport modes for cars. Blad et al. (2022) thus distinguish hubs based on offered transportation modes, location, and target group. In addition to this, Weustenenk & Mingardo (2023) propose a typology based on the differences in offered facilities and services, transport modes, location, and scale resulting in six hub types. Compared to Blad et al. (2022), they add facilities and services and the scale to the definition of the hub.

To keep the size of this master's thesis within limits, the number of hubs is reduced to two: the urban and regional hub. A broad definition for both is used while combining the definition of both articles. The hubs differ in terms of location (distances to be covered) and available transportation modes. Moreover, while both hubs aim to reduce car use in general, they serve different social goals. Both hubs can offer the same facilities and services and can be large and small in terms of scale.

The urban hub is located outside the central part of a city where people, who, for example, depart from a rural area using their private cars, can switch to other forms of transport before entering the city. Thus, the hub is located in dense areas, and shorter distances to the destination are covered from the hub. When the hub is located close to the center of urban areas, it can improve the livability of the city by reducing congestion and emission and increasing livable space (J.-J. Witte et al., 2021).

Regional hubs can be established on central locations in more rural areas. The regional hub contributes to inclusiveness and accessibility (J.-J. Witte et al., 2021). The population density in rural areas is shrinking and is often already relatively low, which complicates the availability of public transport (Frank et al., 2021). Because of low demand, rural regions are often underserved by public transport (Coenegrachts et al., 2021). Shared mobility services can also be complex as they require a minimum density level to be financially viable. This results in increased dependency on private vehicles. Another externality is that accessibility for those who do not own a car decreases drastically, resulting in exclusion from society, also called transport poverty (J.-J. Witte et al., 2021).

Regardless of the location of a hub, for it to attract travelers and convince car drivers to give up their private vehicle, it has to offer competitive transport alternatives to the private mode. Table 4 presents an overview of the urban and regional hub.

Table 4 Overview characteristics urban and regional hub

Urban hub	**Regional hub**
• Located outside of but near the central part of a city, densely populated	• Located in rural areas, not densely populated
• Shorter distances to be covered to the hub and destination	• Larger distances to be covered to the hub and destination
• Improves livability of the city by reducing traffic congestion and space occupied by cars	• Contributes to inclusiveness and accessibility by offering alternative transport modes
• Offering various transport modes	• Offering various transport modes
• Offering various facilities and services	• Offering various facilities and services

To substitute private cars and travel via the mobility hub, travelers should change their current travel behavior. This is, however, often difficult to accomplish, especially when behavior has already occurred frequently, as people are more likely to behave similarly in the future (Bamberg et al., 2003). Hence, if people are used to traveling by car, it is difficult to change their behavior to using other (more sustainable) transport modes in the future. Also, cognitive dissonance plays a role. Many people acknowledge that change is necessary but do not act like it (Tertoolen et al., 1998). This can, for example, be seen in the number of cars in the Netherlands which is only increasing, and growing even faster than the number of Dutch inhabitants (CBS, 2020). Especially among older people, this trend is occurring (CBS, 2021c). The number of cars among younger people is slightly reducing (CBS, 2021c) and the numbers also show that the ownership of electric and hybrid cars is increasing (CBS, 2022a). While the latter is a promising trend from the perspective of greenhouse gas emissions, it does not solve the lack of space in urban areas or accessibility problems in rural areas.

These numbers might suggest that people are attached to their private vehicles despite the (well-known) negative consequences. Autonomy is one of the important reasons for car ownership (Hunecke et al., 2021). It offers flexibility as users can go whenever they want without being dependent on a (public) transport scheme, which is often perceived as insufficiently connected and accessible (Machado et al., 2018). On top of that, urban sprawl is viewed as a reason for car ownership as distances become longer (Machado et al., 2018) as well as the speed the car provides (Ibrahim, 2017). These are examples of instrumental functions of the car resulting in ownership (Burlando et al., 2019). The car also has a symbolic function which refers to one's status when owning a car (Machado et al., 2018). Individuals can, for example, express their social position by means of a vehicle. This shows that it is a difficult task to replace the car. Although the multimodal mobility hub seems to be a promising concept, it also often involves waiting time and more effort from an individual compared to traveling by a private car (Schakenbos et al., 2016). Therefore, on the one hand, the question arises to what extent the multimodal mobility hub can attract people to substitute their private cars. On the other hand, if a traveler is willing to substitute one's private car, the question arises as to which transport mode(s) one is willing to switch.

As described, in this thesis, facilities and services are part of the mobility hub. Offering these facilities and services can mitigate some of the mentioned negative externalities at the multimodal mobility hub by, for example, providing a more pleasant waiting time and reducing the individual's effort

(Carmo, 2020). Although research (Bell, 2019) points out that behavioral change can be achieved by providing additional facilities and services, it is unknown which facilities and services contribute to what extent in different types of hubs.

As multimodal mobility hubs are currently high on political agendas in the Netherlands, research is necessary. One of the few already existing hub networks is in the provinces of Groningen and Drenthe. The hubs have facilities varying from water tap points to schools (Hub, 2022; OV Bureau Groningen Drenthe, 2020). Other municipalities are currently working on the development of the hubs, such as the Hague (Gemeente Den Haag, 2021), Rotterdam (Gemeente Rotterdam, 2020), and Eindhoven (Metropoolregio Eindhoven, 2020). To stimulate the effective development of the mobility hubs, several questions that have arisen based on this problem definition should be answered. In summary, these were the following. Firstly, it is unclear to what extent the multimodal mobility hub can attract people to substitute their private cars. Secondly, it is still unknown which facilities and services contribute to the attraction of travelers to the hub. Lastly, if a traveler is willing to substitute one's private car, the question arises regarding which transportation modes travelers are (more) willing to use.

1.2 Research questions

Three research questions have been formulated based on the problem definition. First, the thesis investigates to what extent a multimodal mobility hub located in urban and regional areas can substitute private car use. While one of the main objectives of the mobility hub is to reduce private car use, it is not yet investigated if the mobility hub fulfills this potential. A difference is made between hubs in urban and regional areas focusing on the different distances people have to cover to reach the hub and destination. Second, as mentioned in the problem definition, facilities and services can stimulate behavioral change and, in that way, improve the attractiveness of the mobility hub. Therefore, the second research question looks at whether the existence of facilities and services contributes to the willingness to use the multimodal mobility hub. Third, the thesis examines how likely people are to choose a particular transportation within the multimodal mobility hub and what characteristics influence this choice.

Hence, the following research questions are formulated.

- **RQ1:** To what extent is the multimodal mobility hub in urban and regional areas able to substitute car use?
- **RQ2:** Does the existence of facilities and services contribute to the willingness to use a multimodal mobility hub?
- **RQ3:** What is the likelihood of each individual transportation mode to be chosen by those willing to use the hub and which factors influence this choice?

1.3 Research design

The research design for this study is as follows. To start, literature research is performed. A theoretical basis is created to understand the topic and problem clearly. To answer the research questions, a survey with a stated choice experiment is designed. The stated choice experiment describes a situation in which travelers have to choose between traveling by their own car (i.e., sticking to the status quo) or traveling via the mobility hub. Both alternatives are characterized by various attributes. It will be examined which hub, status quo, socio-demographic, contextual, and travel characteristics affect the willingness to use the hub and substitute the private car (Figure 1).

When travelers choose to travel via the mobility hub, they are asked which transportation mode they are willing to use for that particular trip. This choice can be influenced by individual (socio-demographic and individual travel) characteristics and transportation mode characteristics. More specifically for the latter, travel time, travel costs, and arrival frequency are included in the experiment (Figure 2).

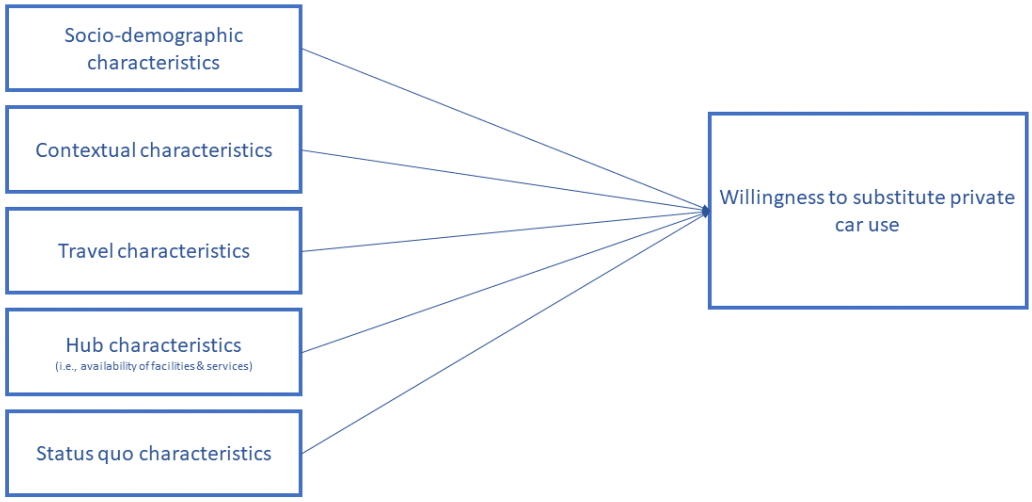

Figure 1 Conceptual model mobility hub choice

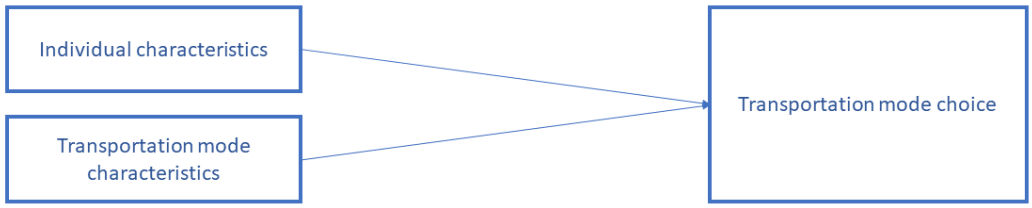

Figure 2 Conceptual model transportation mode choice

1.4 The practical/social and/or theoretical/scientific importance of the thesis

This thesis aims to contribute to several practical and societal goals. The findings from the thesis can help municipalities design the multimodal mobility hub. The thesis can serve as guideline by providing information facilities and transportation modes at the hub. Such evidence-based design can increase the adoption of hubs and contribute to creating a healthy living environment in urban areas while improving the accessibility and inclusiveness of residents in rural areas.

The theoretical contribution of the current research is multifold. First, it aims to determine to what extent the multimodal mobility hub in urban and regional areas can substitute private car use. Although an increasing number of articles is currently written about the mobility hub, it is still an emerging concept that needs attention. To the author's knowledge, two studies can be found concerning a similar topic. The research of van der Meer (2022) focuses on the intention to use neighborhood hubs, however, it mainly focuses on identifying user groups by conducting a latent class cluster analysis. Claassen (2020) investigated the reduction of car ownership through a neighborhood mobility hub by offering shared mobility modes. This master's thesis contributes to the literature by conducting a stated choice experiment among frequent car drivers, focusing on the substitution of car use by traveling via an urban or regional hub. In addition, since the use of the mobility hub implies a shift from the private car to alternative transport modes offered at the hub, the current study aims to

examine the type of modes to which travelers will switch once they use the hub. This information helps to provide a more realistic evaluation of the impacts of hubs on the mobility demand and the types of mobility forms that should be offered. Lastly, it aims to find out the effects of having various facilities and services within the hub in regard to attracting travelers, which is a topic that has received little attention.

1.5 Reading guide

The outline of this thesis is as follows (Figure 3). Chapter 2 includes a literature review. Among others, it explains concepts influencing the utility of a trip, tangible aspects of the hub, and previous mobility policies. In Chapter 0, the research design of this study is explained. This includes the explanation of the structure of the survey and the design of the stated choice experiment. Chapter 4 explains the data collection and preparation process. Also, a description of the sample is included. Chapter 5 discusses the data analysis and results. Finally, the thesis is discussed in Chapter 0.

Figure 3 Outline of the thesis

2 Literature review

This chapter provides a theoretical basis for this research. It discusses four elements of the utility of a trip (2.1), tangible aspects of a hub (2.2), the connection to other new mobility (MaaS and DRT) (2.3), and previous mobility policy (2.4)

2.1 Utility of a trip

In daily life, people often make a simple tour in which the traveler only makes two trips, for example, from home to work, and from work to home. A trip is thus one-way, for example, only from home to work. Travelers can also make a complex tour where more than two trips are involved and more than one travel purpose (Daisy et al., 2018; Rafiq & McNally, 2021). This research focuses on the multimodal trip, indicating that one uses more than one transport mode in one trip. The multimodal trip can be characterized by three phases: the first and last mile, also called access and egress, and the main stage which is typically the stage covering the greatest distance between the first and last mile (Stam et al., 2021). From the behavioral economic perspective, people arrange their trips in such a way as to maximize their utility (H. T. K. Le et al., 2020). Utility expresses the usefulness or benefit one derives from particular aspects or characteristics (Broome, 1991). Schakenbos et al. (2016) identified three components influencing the (dis)utility of a trip: travel time, costs, and effort. In addition to this, a fourth component is identified: travel-based multitasking. Mitigating the negative impact of these four components when traveling via a multimodal mobility hub reduces the disutility of the particular trip and thus may result in a higher willingness to use. In the following, the four components will be further elaborated.

Figure 4 Multimodal trip

2.1.1 Travel time

The first component concerns travel time. This includes the time one is moving from origin to destination, the time at the origin and destination (waiting time), and the time for the first and last mile (access and egress time) (Schakenbos et al., 2016).

Waiting time

The waiting time can be measured objectively (actual transfer time) and subjectively (perceived waiting time) (Fan et al., 2016). While research is not consistent about the exact number of the multiplier, which is 'the ratio of perceived waiting time to either actual waiting time or in-vehicle time' (Fan et al., 2016, p. 251), all show that the perceived transfer time is longer than the actual transfer time. Some studies argue that the perceived waiting time is two to four times longer than the actual waiting time and others argue that this is 'only' 1.5 times longer (Fan et al., 2016; Ingvardson et al., 2018; Warffemius, 2015).

When a person needs to transfer multiple times, this inconvenience can result in a less pleasant trip experience (Schakenbos et al., 2016). To this end, the presence of other facilities such as a café, supermarket, or a parcel pick-up point can increase the attractiveness of the hub in several ways (Bell, 2019). The utility of waiting time can be increased by providing station amenities for comfortable

waiting, working, and relaxing (Fan et al., 2016; Schakenbos et al., 2016) increasing the tendency to switch to alternative transport modes. Providing such facilities as part of the mobility hub can also provide convenience, as one of the reasons often mentioned for the tendency of using one's private car is the easiness of multiple trip purposes within one tour (from origin to destination) (Ho & Mulley, 2013). Doing grocery shopping on the way back from work and posting a letter/package could be examples of those activities. When the distance between these activities grows, people are more likely to use the car over shared and collective modes of transport (Ho & Mulley, 2013). At the hub, amenities can be offered centralized, allowing one to conduct multiple activities without making extra stops.

Moreover, travelers usually have a critical waiting time which indicates the maximum duration passengers are willing to wait at a transit stop before they opt out for an alternative transport option (Roy & Basu, 2021). The critical waiting time is not the same for each transport mode. Roy & Basu (2021) found in their study that the critical waiting time for travelers by bus is 15 minutes, and for traveling by shared car 8 minutes. The maximum waiting time for the subway is estimated at 10 minutes (Li et al., 2018). Besides, the maximum waiting time also depends on the duration of the total trip. Fan et al. (2016) found that transfer time plays a more significant role in short-distance trips than long-distance trips. This seems logical as transfer time plays a relatively more significant role in short-distance trips. In addition, if no amenities are offered at a transit stop, the perceived waiting time increases (Fan et al., 2016). This effect is stronger for women than for men because women often feel unsafe at stops (Chowdhury & van Wee, 2020; Fan et al., 2016). This results in women choosing another transport mode when waiting time becomes more than 10 minutes. Offering basic amenities at stops can reduce this effect (Fan et al., 2016).

Access and egress time

The distance to access the hub for the first mile also seems to be an important factor when traveling, as people aim for a minimal travel distance (Brooks et al., 2008). It is, therefore, likely to assume that people are less willing to use the hub if the hub is located too far away from their starting point. Research shows that people are willing to walk 500 meters to a subway station (Li et al., 2018), ideally, 400 meters to a bus station and 800 to a train station, and up to 1000 meters to public transport stops in general (Stanesby et al., 2021). At a mass rapid transit (MRT) station, people are willing to travel for 7 to 10 minutes regardless of the travel mode (Mo et al., 2018) (and 10 minutes of walking covers around 800 meters). Travelers are thus willing to travel slightly longer to MRT stations than to a subway or bus station. This difference could possibly be explained because the MRT station offers more transport modes.

The distance to the hub also influences the transport mode with which one is arriving at the hub. The closer a transit station is to the start location (often home), the more likely one will use an active transport mode (by walking or bike) to get to the hub. Similarly, the willingness to walk reduces when the distance increases, resulting in people using faster transport modes such as the private car. However, the downside to people using a private car to travel to the hub is that, as mentioned, they are more likely to continue their trip by private car instead of traveling via the hub (Mo et al., 2018).

Just like the first-mile travel distance, last-mile travel time is preferred to be as low as possible. The travel time from the hub to the POI mustn't be (a lot) longer than the travel time one would have when traveling by private car. The last mile travel time depends on the location of the hub towards the POI and the transportation mode one uses.

2.1.2 Costs

The second component influencing a trip's (dis)utility is costs, referring to the costs the traveler must make when traveling. For example, a bus ticket should be bought when using public transport. However, one can also think of the car's parking or fuel costs. Preferably, traveling via the mobility hub results in comparable or lower costs compared to the regular way of transportation (for example, when traveling by a private vehicle). This can be accomplished by providing free or low-cost parking at the mobility hub and implementing stricter parking policies and higher parking fees in the city center (J.-J. Witte et al., 2021). This suggests that the mobility hub is not a complete solution for car-oriented problems but is a policy that should be used in combination with other policies.

2.1.3 Effort

The third component concerns effort in terms of individual's affective, cognitive, and physical effort required during the trip. The effort can be reduced by elements such as information provision, safety, and facilities on the location (Cascetta & Cartenì, 2014). The utility increases as the required effort decreases.

2.1.4 Travel-based multitasking

A fourth component affecting the (dis)utility, although not mentioned in Schakenbos' study, is travel-based multitasking. Driving a car eliminates the possibility of conducting any activities while traveling. Studies showed, however, that multitasking can increase the utility of trips as one can be productive while traveling (Rasouli & Timmermans, 2014; Singleton, 2018).

2.2 The multimodal mobility hub's tangible aspects

This paragraph discusses the tangible aspects of a multimodal mobility hub. This includes facilities and services, and transport modes.

2.2.1 Facilities and services

Providing facilities at a multimodal mobility hub can reduce one's effort and consequently decrease the disutility of a trip. Three categories of facilities and services are identified that can be provided at a mobility hub: primary, secondary, and ancillary facilities and services (Carmo, 2020).

Primary services, such as travel information, ticket sales, and waiting areas, must be available at each hub. The presence of such facilities reduces travel resistance (Carmo, 2020; J.-J. Witte et al., 2021) and the perception of waiting time (Fan et al., 2016). These facilities are considered indispensable at the hub.

Secondary or complementary services contribute to a more pleasant waiting time for travelers, of which food and drink machines are examples. Although it is called a secondary service, this kind of service is essential in reducing waiting resistance as well as the disutility of a trip. A challenge is to reach a mass point for this kind of facility. For example, a food and drink machine requires 2,000 travelers daily (Carmo, 2020). The required passenger demand only increases with adding the third category of services, which refers to related or ancillary services. These services are not directly associated with transport or travelers but are "daily services and serve as links between transport and urban fabric (daycare facilities, co-working spaces, general stores)" (Carmo, 2020, p. 69).

While the secondary services reduce the disutility of waiting time for travelers, the ancillary services can attract other customers besides travelers. For example, when an individual has three destinations or POIs during the day in the following order: work, the supermarket, and home, the individual can reduce travel time when traveling via the hub by doing grocery shopping in a store that is now offered at the hub. This means it reduces the individual's effort and (travel) time. Although it is often stated

that facilities are preferred at transfer locations, it is not yet examined which facilities contribute to using the mobility hub.

As mentioned, it is assumed that primary services must be available at each hub. This includes facilities such as travel information, ticket sales, benches, and waiting areas. However, it should be mentioned that this also comes with costs. Moreover, the location is important for secondary and ancillary services when deciding which facilities and services should be offered (Carmo, 2020). Current developments and daily travel patterns of travelers have been investigated to propose facilities, eventually aiming to reduce the number of trips by traveling via the hub.

2.2.2 Transportation modes

The design of the multimodal mobility hub might influence whether people are willing to travel via the hub. In section 2.2.1, the importance of facilities and services at a hub is already discussed. Besides this, the multimodal mobility hub should offer multiple transportation modes for travelers to switch to from their current mode of transport. Multiple studies are conducted to discover preferences regarding transportation modes (e.g., Stam et al., 2021) and the reason for choosing a particular travel mode (Li et al., 2018). These results are, however, without considering whether the traveler is also willing to give up their current mode of transport.

Having three stages in a trip (i.e., access/egress and main phase) also means that the traveler must choose the way of transportation three times. For the first and last mile trip, Stam et al. (2021) distinguish six categories influencing the mode choice of travelers: characteristics of the traveler, psychological factors, characteristics of the first/last mile trip, characteristics of the first/last mile modes, characteristics of the built environment, and main stage factors. Li et al. (2018) found in their literature review that time, costs, and distance for travel, the need for private space and safety, perceptions, the purpose of the trip, habits, and status are determinants of the mode choice. These factors can also be classified into the six categories mentioned by Stam et al. (2021).

As mentioned, the multimodal mobility hub will offer different transportation modes. The following gives a brief overview of potential modes at the hub.

Public transport

Public transport can include multiple modes and depends on which modes are offered in the area. The most common public transport modes are the bus and train. While the bus is often used for short distances and is more flexible, the train is usually used for longer distances. Public transport also includes tram and metro. However, only a few cities in the Netherlands facilitate these transport modes. In this research, the regional hub includes the train as transport mode because longer distances will be covered. The urban hub includes the bus instead of the train because shorter distances will traveled from the hub.

Shared mobility

Shared mobility originated from the sharing economy. For shared mobility, individuals get rid of ownership and instead share transport modes (Santos, 2018). This is on a short-term and as-needed basis (Shaheen et al., 2019). This concept can potentially reduce congestion and emissions, depending on the (shared) transport mode one decides to use (Santos, 2018). Santos (2018) distinguishes four shared mobility models for car-sharing. The first model is peer-to-peer car rental. Individuals or private car owners can rent their car to someone when they do not use it. While a company can act as a broker, it is not the owner of the car. An example in the Netherlands of a company acting as a broker is Snappcar. The second model is the modern car club. Here, vehicles are rented out by a company for

the short term. The cars are parked in designated places or public spaces in a city. This model is also called a free-floating system (Bojković et al., 2019). It is also possible that the rented car must be picked up and returned at the same (fixed) location. This is called a station-based system of the modern car club model (Bojković et al., 2019). Dutch examples of a free-floating and station-based car rental system are Amber and Greenwheels. The third model described by Santos (2018) is the Uber-like service, also known as ride-hailing or ride-sourcing (Tirachini, 2020). This model is not based on owning cars but on renting drivers. The company rents private drivers through an app and takes a percentage of the total payment of the consumer. As the model's name already indicates, a company operating in the Netherlands following this model is Uber. The last model is new public transport on demand, also known as demand responsive transport (DRT). People simultaneously share a vehicle (i.e., car, van, bus) when traveling in the same direction. The difference with carpooling is that the driver is hired and employed by a (public transport) company. The model is more flexible than traditional public transport as individuals can be picked up at locations not covered by public transport by registering your trip, pick-up location, and destination. An example in the Netherlands of this model is Bravoflex. This model is further discussed in section 2.3.

In addition to these four models, the taxi is also a way of shared mobility. It differs from the Uber-like service as it does not concern private drivers but drivers employed by a company.

Santos (2018) (mostly) focuses on car mobility while shared mobility also includes shared micro-mobility. Shared micro-mobility encompasses the share of (e-)bikes, (e-)scooters, and other low-speed transport modes (Reck & Axhausen, 2021). As well as the shared car, the shared micro-mobility forms can be divided into the free-floating and station-based systems. As it aims to reduce car ownership and use, shared micro-mobility is a good alternative. Currently, shared micro-mobility is becoming more and more popular while municipalities are struggling with the concept. The shared scooters and bikes cause a nuisance as they can be parked anywhere. This means that they are often on pavements blocking the way for pedestrians but also for physically impaired people resulting in many complaints (NOS, 2020). Micromobility is, however, still allowed in the Netherlands.

2.3 Mobility-as-a-Service and Demand Responsive Transport

When talking about new ways of (organizing) mobility, at least brief attention must be paid to Mobility-as-a-Service (MaaS) and Demand Responsive Transit (DRT). Although this is out of the scope of this research, the concepts are closely connected to the multimodal mobility hub.

MaaS is a digital service integrating different transportation services into one digital application (Feneri et al., 2020; Rongen et al., 2022). Travelers can subscribe to the service and buy a particular package based on their mobility needs. These packages can vary from having access to the shared bike for a reduced tariff to having unlimited access to public transport or a combination of both (Feneri et al., 2020). Consequently, the app suggests the best trip from origin to destination (including the first and last mile, and the main stage), which can then be booked and paid for in that same app (if still necessary). Transportation modes offered in the application differ based on the operators that participate in the service. However, one can usually think of transport modes as shared modes, public transport, and taxis. Demand Responsive Transport (DRT) is also often part of MaaS practices which is especially useful in rural areas with low mobility demand.

Demand Responsive Transport, or abbreviated DRT, is a collective on-demand service offering a more flexible and cost-effective way of public transportation services and is suitable in low-demand areas (Davison et al., 2012; Gonzalez et al., 2021). It thus entails a combination of on-demand and traditional public transport services (i.e., fixed bus lines). The most important aspect of DRT is that there is no fixed timetable but travelers make a reservation shortly before their departure. This can, for example,

be facilitated by the MaaS application. Travelers indicate at which location they should be picked up, at what time, and what their destination is. Subsequently, the travelers get picked up by a (shared) vehicle. As such, DRT can complement or substitute fixed (traditional) public transportation in rural areas. DRT is already operational in several areas of the Netherlands, of which Bravoflex is an example running in the Noord-Brabant region. Combining passenger demand with, for example, parcel delivery demand in areas where both demands are insufficient is yet another way to make shared vehicles able to operate in rural areas so that they are still financially viable.

Both concepts are connected to the multimodal mobility hub and to each other. On the one hand, MaaS can facilitate the multimodal trip and, consequently, the multimodal mobility hub by suggesting an efficient trip via the hub. It can also minimize the transfer time for travelers at the hub, reducing the so-called transfer penalty referring to the mental effort that comes with it (Rongen et al., 2022). MaaS can improve the adoption of the mobility hub. On the other hand, the mobility hub facilitates MaaS by offering multiple transport modes at one location, encouraging other transport mode operators to provide their services on that location as well (Rongen et al., 2022). J.-J. Witte et al. (2021) call the mobility hub the physical factor of MaaS. As mentioned, DRT can, for example, be offered at the hub. It can be a fixed point for the DRT services that might have the potential to replace fixed public transport. This way, DRT demand is centralized at recognizable locations (Rongen et al., 2022).

In conclusion, the mobility hub, MaaS, and DRT complement each other when centralized at one location. This research focuses on the hub, but MaaS and DRT should not be forgotten in practice.

2.4 Previous mobility policies

The multimodal mobility hub is not the first attempt by governments to reduce (private) car use. Several strategies are applied to discourage people from using the car. These strategies can be categorized into push and pull measures. Push measures are driving people away from behaving in a certain way (Kuss & Nicholas, 2022). In this case, push strategies should discourage people from using a private car such that they will use another transport mode. Examples of push measures are (higher) taxes on car ownership or (higher) parking fees. Pull measures aim to attract people to behave in a certain way, in this case, by making other transport options more attractive ((Kuss & Nicholas, 2022). Examples of pull measures to incentivize people to travel more sustainably are improved public transport, improved bicycle infrastructure, and the development of Park and Ride (P+R) locations. The mobility hub can be categorized as a pull measure that increases the convenience of using collective transport. Although research shows that travelers are more interested in pull measures (e.g.,Bardal et al., 2020), it is not yet proven how effective a multimodal hub is and whether people will change their behavior by substituting their private car.

Learning points of (previous) related policy concepts should be considered when developing mobility hubs. As mentioned, one of the pull measures of the government is the development of P+R locations which are closely related to the concept of the mobility hub. This concept shows several learning points.

P+R facilities aim to incentivize the use of public transport by providing parking spaces near public transport stations. In this way, policy-makers aimed to minimize transfer resistance and target car users to cover part of their journey by public transport (Rongen et al., 2022). It is a concept that stimulates the use of the car for one part of the trip after which the trip can be continued by public transport. Thus, the P+R concept also encourages multimodal behavior. However, it also showed that if the P+R is located too close to the area of interest, travelers still prefer to use the car as only a short distance has yet to be covered (Rongen et al., 2022). Moreover, if sufficient parking facilities at the destination are price competitive, people also often still use the car for the whole trip (J.-J. Witte et

al., 2021). Thirdly, the P+R is designed explicitly for (parking) cars. This means that a P+R facility expands the car infrastructure and results in even more car use (J.-J. Witte et al., 2021). That is an essential point of consideration in finding an appropriate location for the hubs in order to maximize the tendency to reach there by non-private vehicles. Although the multimodal mobility hub differs from the P+R facility in terms of design, it has the same objective, i.e., reducing car use and attracting travelers toward multimodal behavior. Therefore, these learning points should be considered when designing the mobility hub. This thesis will not specifically cover all these learning points. Locating the hub is already discussed by Aydin et al. (2022). The second learning point is a matter for the government/municipalities to ensure that there are multiple complementary policies to stimulate the use of transport modes other than cars. This research considers parking prices.

2.5 Conclusion

This chapter presented a theoretical foundation for the study. After defining the multimodal mobility hub in Chapter 1, this chapter described how individuals derive utility from a trip. The key factors affecting this utility are travel time, costs, effort, and travel-based multi-tasking. Consequently, the hub's tangible aspects were described. The review showed that a hub could include primary, secondary, and ancillary facilities and services. Primary services are indispensable, while secondary and ancillary services can attract travelers but also other customers to the hub. Moreover, potential transportation modes are presented and categorized into public and shared transport. This chapter also highlighted the significance of MaaS and DRT, which are closely connected to the multimodal mobility hub. Both MaaS and DRT have the ability to enhance the adoption of the hub. Finally, previous mobility policies were discussed. The multimodal mobility hub is a pull measure related to P+R facilities. Based on the latter, several learning points should be taken into account. This research considers one of these points (i.e., parking prices).

3 Research design

This thesis aims to answer three research questions as defined in section 1.2. Specifically, the main objectives of this thesis are to investigate to what extent the multimodal mobility hub can substitute travelers' car use and which factors influence this choice, whether the existence of facilities contributes to the willingness to use the hub, and how likely people are to choose a particular transportation within the multimodal mobility hub and what characteristics influence this choice. A stated choice (SC) experiment is designed to capture travelers' willingness to adopt the mobility hub and replace their private cars with alternative modes offered within the hub. The SC experiment is included as part of a survey distributed to a panel consisting of the Dutch population. In section 3.1, the structure of the survey is explained. Section 3.2 provides details on the (design of) the SC experiment.

3.1 Survey set-up

The survey is structured in six sections as viewed in Figure 5.

Figure 5 Survey structure

Part 1 introduces the research to potential respondents. This part explains the research objective and a consent form explaining the privacy policy as personal data will be collected. The respondents must agree with the privacy policy; otherwise, they cannot continue the survey. The contact details of the researchers are also provided in this section in case of problems and/or questions. Appendix E presents the consent form.

Part 2 of the survey includes three screening questions. All participants should fulfill three requirements to be able to continue filling in the survey. The requirements include possessing a driver's license, owning at least one car, and driving the car at least once per week. More particularly, the following questions are asked in this section:

- Do you own a driver's license?
- How many private cars does your household own?
- How often do you drive a car?

Once participants answer the questions following the requirements, they can continue the survey.

Part 3 of the survey contains questions concerning various aspects related to participants' private car and other transport modes owned and used by them. It covers topics such as the ownership status of the primarily used car (privately owned, corporate lease, private lease), fuel type of the car, type of micro-mobility modes available in the household, as well as the frequency of being a passenger in the car.

Part 4 contains questions about collective and shared transport modes. Specifically, questions are asked about ownership of an OV-chipcard (Dutch public transport card), familiarity with the shared e-bike, shared e-scooter, and shared car, and travel time to the nearest bus and train station.

The stated choice experiment is included in part 5. Before presenting respondents with the stated choice tasks, information about the concept of multimodal mobility hub and other new and likely unknown concepts are introduced by showing a video and/or pictures with a written explanation. Then, in each choice task, respondents are presented with eight choice representing hypothetical scenarios that differ from one another in various aspects, such as total travel distance, the distance to

the hub, travel costs, facilities available at the hub, etc. The respondents are asked whether they would continue using their private car or travel via the hub. If they choose to use the hub, they are asked to select one of the transportation modes available within the (hypothetical) hub. Section 3.2 provides more details on the SC experiment.

Part 6 of the survey asks a set of questions regarding the intention to use facilities that can be available within the hub. Also, question about their attitudes regarding multimodality (S. Kim & Rasouli, 2022) and environmental friendliness (J. Kim et al., 2017) are asked. The responses regarding the use of facilities are recorded on a 5-point Likert scale from never to very often, while the attitudes are measured using a total of seven statements (three for multimodality and four for environmental friendliness) on a 5-point Likert scale from strongly disagree to strongly agree.

Lastly, in part 7, questions about socio-demographic characteristics are asked, allowing us to explore the differences and similarities between these groups. No unnecessary (personal) data with the potential to reveal one's identity, such as name, date of birth, or IP address are collected.

3.2 Stated choice experiment

In general, two types of choice experiments can be distinguished, as viewed in Figure 6 (Kemperman, 2000). The first type is revealed choice/preference data which is based on real choices in real market situations. The data are based on past decisions and the research subject already exists. The second type is stated choice and preference data based on choices in controlled hypothetical scenarios. It can therefore provide information about behavior regarding a product or service which does not yet exist in the market. This approach is also suitable for cases where the study concerns a rare product or service for which data is scarce. Considering the multimodal mobility hub, the stated choice approach fits this research better as the multimodal mobility hub is a relatively new and emerging concept that is not yet widely used among travelers and is at the early stage of implementation. Moreover, within the stated approach, a distinction is made between stated preference (compositional and decompositional) and stated choice. For the compositional stated preference approach, each attribute must be rated separately on importance based on a prespecified scale. For the decompositional stated preference (conjoint preference) approach, a trade-off must be made between attributes. Stated preference data thus present rankings or ratings of a set of alternatives. For the stated choice approach, respondents must choose one alternative consisting of multiple attributes out of a few alternatives. The respondents choose the alternative that fits their preferences in the best way. This trade-off approach is most similar to real-world choices and is, therefore, most suitable for this research.

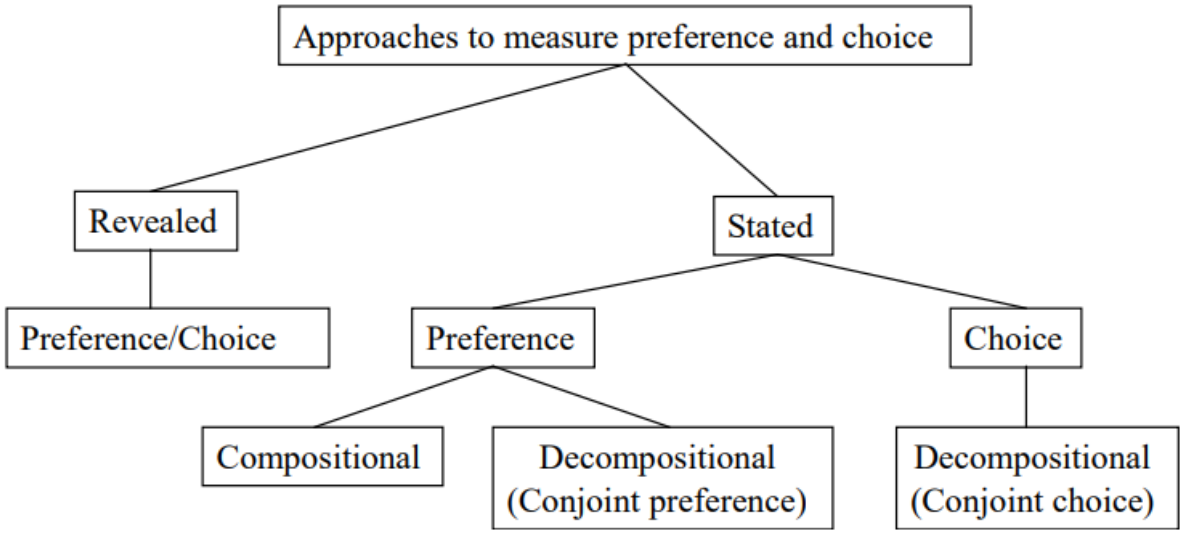

Figure 6 Overview of preference and choice measurement approaches (Kemperman, 2000)

The suitability of the SC experiment (compared to the revealed choice) is not constrained to new products and services (Kemperman, 2000). In revealed preference data, attributes often correlate with each other, which is not desired for statistical analysis, whereas in the SC experiment, the choice sets can be fully controlled and zero correlation can be maintained between attributes. Moreover, multiple observations per respondent can be collected in the stated choice approach instead of only one in the revealed experiment, which leads to a lower required number of people to approach for data collection. This is because multiple choice tasks can be presented to a single respondent in an SC experiment.

Although the SC approach offers these advantages, it also encompasses limitations (Hensher et al., 2015c). Firstly, uncertainty exists about people's actual choices, also called the issue of realism. Although the respondents state that they will choose a particular alternative during the experiment, it is uncertain whether they would also choose this alternative in a real-life context. Secondly, the alternatives may be too hypothetical for a specific individual affecting the relevance of the results. Therefore, making the choice options as realistic as possible is important. However, what is viewed as realistic differs per individual. For example, when people consider traveling via a mobility hub, some people may find the 35-minute trip alternative realistic (and beneficial) compared to their current situation because they usually travel 40 minutes by car. Others may typically travel 10 minutes by car and, therefore, may find the 35 minutes unrealistic (and non-beneficial) for their situation. Thirdly, the data are not directly related to behavioral change. While an alternative can be assessed as the best of the set of alternatives, no data are available on whether the individual would change to that alternative. This last limitation can be overcome by including an option where the respondent indicates to choose neither of the alternatives. An additional limitation concerns the number of attributes and attribute levels that should be limited. When the design includes too many attributes and attribute levels, the number of required profiles to maintain desired properties (zero correlation between attributes and attribute balance: all levels of attributes appear the same number of times) is too high. This increases the burden for respondents, which may bias their responses (Arentze et al., 2003; Jang et al., 2022), or requires a larger number of people to respond.

3.2.1 Design of the stated choice experiment

The following steps for experimental design (Hensher et al., 2015) are used as guideline to design the stated choice experiment. In Figure 7, the scheme of this process is visualized.

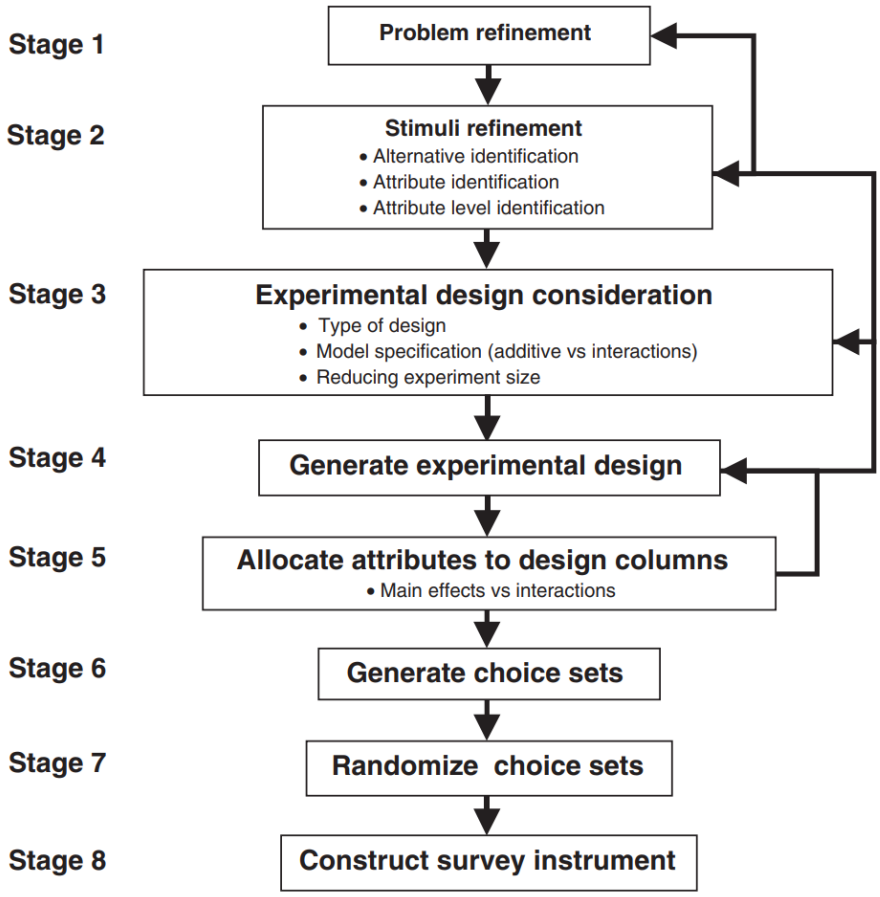

Figure 7 Stages for experimental design (Hensher et al., 2015)

3.2.1.1 Stage 1: Problem refinement

The first stage of the experimental design is to ensure that the problem is clearly defined and, when necessary, refined by removing irrelevant (parts of) questions. In section 1.1, the problem definition is elaborated through literature research. During (the process of) the literature review, the research questions are refined and reformulated.

3.2.1.2 Stage 2: Stimuli refinement

This stage consists of three steps: identification and refinement of the list of alternatives (1), attributes (2), and attribute levels (3).

The first step is a refinement of the list of alternatives. Central questions in this research are whether people would travel via a multimodal mobility hub and which transportation mode they would choose. Therefore, hypothetical travel situations are outlined in which travelers choose how they prefer to travel. The alternatives are sticking to the status quo (i.e., the private car) (alternative 1) or using the multimodal mobility hub (alternative 2). If the latter is chosen, the respondents are asked to select one transport mode out of four depending on the type of hub they are presented (i.e., the urban or regional hub). The four alternatives for the transportation mode choice are the shared e-bike, shared e-scooter, shared car, and the bus (urban hub) or train (regional hub).

The second step is to identify the list of attributes. Firstly, a finite list of all possible attributes is defined. Literature research is conducted to create a primary list of attributes. Subsequently, if the list of attributes is long (which was the case in this research), some decision-makers can be consulted to select the most important attributes. The downside is that this process is time-consuming. Alternatively, the researcher can exclude insignificant attributes. While the decision might be more subjective, it would fit the time available for this master thesis and is therefore adopted for this work.

Thirdly, attribute levels are identified after determining the final list of attributes. Determining the appropriate number and range of attribute levels requires careful consideration of several issues. In this thesis, an even number of levels is chosen for each attribute, as combining odd and even numbers of levels leads to a larger design size. Moreover, a tradeoff is made between the amount of information reflected by the number of levels and the size of the design. While more levels might result in more information and higher accuracy, it also requires a larger sample size, and an insufficient sample size reduces the reliability of the study. In addition, to the extent the purpose is to examine any non-linear relationships between attributes and the choice, at least three levels per attribute are required. That is because two levels would only allow the estimation of linear relations. Besides deciding upon the number of attribute levels, the range of the levels' values are determined. The challenge is to create competitive trade-offs while the levels are still realistic and within the range of one's current experience.

Final attributes and attribute levels

The following part presents and discusses the results of this identification and definition process. The attributes are divided into three parts: the contextual attributes (1), the status quo attributes (2), and the attributes of the mobility hub, the transportation modes, and facilities (3). A distinction is made between the urban and regional hub for some attributes. This distinction is made for two reasons. First of all, the distance between one's home and the urban hub is typically smaller than that of the regional hub. Therefore, there is variation between the distances from origin to destination and from origin to hub. Second of all, as larger distances are traveled, the train is included as part of the transportation modes in the regional hub while it is replaced with the bus in urban hubs. In this way, we can find out if the variety of the available modes can impact the decision of respondents in choosing hubs. Table 5 shows an overview of the attributes and attribute levels. The attributes and their levels are elaborated in the following part.

Table 5 Attributes and attribute levels for the urban and regional hub

Attribute	Attribute level	
Contextual attributes		
Weather	Sun/Rain	
Primary travel purpose	Work/Leisure	
Other activities	Grocery shopping/picking up a package/business meeting/dropping-off-off and picking-up children from daycare	
Status quo attributes	**Urban**	**Regional**
Travel distance from origin to destination (km)	3/7/11/15	10/25/40/55
Parking costs at destination (€)	0/4/8/12/16/20/24/28	0/4/8/12/16/20/24/28
Hub attributes	**Urban**	**Regional**
Multiplication factor	0.80/1/1.20/1.40	0.80/1/1.20/1.40

Arrival frequency bus (x times per hour	2/4	-
Arrival frequency train (x times per hour)	-	2/4
Distance to the hub in km (urban) and percentage of travel distance from origin to destination (regional)	0.5/1/1.5/2	30%/40%/50%/60%
Transfer time (min)	1/3/5/7	1/3/5/7
Parking costs in the hub (€)	0/8	0/8
Transport mode attributes	Urban	Regional
Tariff for the bus (€/km)	0.13/0.17/0.21/0.25	
Tariff for the train (€/km)		0.15/0.2/0.25/0.30
Tariff for the shared e-scooter (€/km)	0.5/0.65/0.8/0.95	0.5/0.65/0.8/0.95
Tariff for the shared e-bike (€/km)	0.4/0.5/0.6/0.7	0.4/0.5/0.6/0.7
Tariff for the shared car (€/km)	0.51/0.66/0.81/0.96	0.51/0.66/0.81/0.96
Facilities		
Supermarket	Yes/No	
Parcel pick-up point	Yes/No	
Café	Yes/No	
Day care	Yes/No	
Gym	Yes/No	
Drug store/medicine pick-up point	Yes/No	
Social extended reality office space	Yes/No	

Contextual attributes

The contextual attributes provide information about the context in which the decision is made. Specifically, the weather, primary travel purpose, and other activities are included as attributes in the SC question.

Weather

The weather is a determinant of travel behavior and mode choice. Scholars identified that weather conditions, especially good and bad weather, play a significant role in determining travel patterns. Good weather conditions, often characterized by sunny and dry days, tend to encourage active transport modes such as biking (Böcker et al., 2016). Conversely, bad weather conditions, such as rainy and windy days, tend to discourage the use of active modes and result in a greater reliance on private cars (Hyland et al., 2018). This phenomenon can be explained by the fact that walking or cycling in bad weather can be uncomfortable and inconvenient, and waiting at transit stops is generally undesirable. Therefore, a differentiation is made between sunny and rainy weather conditions to gain insight into how different weather patterns impact the choice between the status quo and the mobility hub.

Primary travel purpose

This research distinguishes two primary travel purposes: going to work or going out for a leisure activity. Only two primary travel purposes are chosen for the simplicity of the design. Most trips are made for shopping (groceries and fun shopping) and work (CBS, 2022b). Leisure is found to be a common travel purpose as well (i.e., third in most common travel purposes) (Krueger et al., 2016). Based on this, it is chosen to exclude (grocery) shopping from the list of primary travel purposes as it is unrealistic that people make a multimodal trip of 40 kilometers to a supermarket, for example.

Other activities

During the day, people can have multiple activities. So besides the primary purpose, they can have other activities such as grocery shopping or dropping off and picking up children from daycare. For some of these activities, the availability of facilities might be desirable. To understand if people with different activities in their agenda react differently to the use of the hub, *other activities* is included as an attribute. The mobility hub might attract more travelers by providing facilities at the hub that facilitate conducting these activities. Then instead of the convenience of using their own car to conduct multiple trips, the hub itself can provide this option. The levels of this attribute consist of the following four other activities.

- *Picking-up a parcel*: Over the last few years, the number of packages being ordered is increasing (PostNL, 2021). According to the statistics provided by PostNL, the largest Dutch courier company, households received on average 16 packages in 2020 which is a 27% increase compared to 2019 (PostNL, 2021). While this increase is also due to the pandemic during this year, many people deliver and receive parcels (the average number of packages per household was equal to 12.5 before the pandemic (PostNL, 2021)). While packages can be delivered at home, people often let their orders be delivered at a store or pick-up point. A pick-up point at a mobility hub means recipients can immediately pick up the parcel when transferring via the hub instead of making an extra trip. This also reduces traveled distances as dedicated trips to other pick-up locations will not be necessary.
- *Dropping-off/picking-up children from daycare*: In the Netherlands, more than 541,000 children go to daycare and an extra 535,000 go to school care (CBS, 2022c). One of the reasons to use one's private car might be the necessity to pick up and drop off the child(ren) on the way to another activity location. Providing a daycare facility at the hub may remove such reasoning and act as motivation to leave the private car behind even if a child needs to be escorted to daycare. This can also reduce the number of trips that otherwise would be made to the location of the daycare. While daycare near a transport node is uncommon in the Netherlands, this is already a reality in other countries. In Lyon (France), the Gares and Connexions project started to make it easier for parents to drop off their children at daycare while traveling to work (Carmo, 2020).
- *Grocery shopping*: 61% of Dutch citizens visit the supermarket two to four times a week (Gelder, 2022). This means that it is one of the primary purposes to travel. In the Netherlands, most trips to the supermarket are conducted by bike (40%) or foot (31%) (Tighe, 2021). This is, however, also dependent on the distance to the supermarket and the volume of the purchase. The longer the distance to the supermarket and the larger the shopping volume, the higher the probability that one uses a car to reach the supermarket (Veenstra, 2009). Around 18% of people go to the supermarket by car (Tighe, 2021). Especially for this last group, a supermarket at a multimodal mobility hub can be beneficial.
- *Business meeting*: Multiple authors (Meulepas et al., 2021; J.-J. Witte et al., 2021) propose office areas at the multimodal mobility hub. Providing office and meeting spaces at a mobility hub can have different functions. On the one hand, it provides a place for people who are waiting in between appointments or for their transfer to work. In this way, people can spend their time efficiently if desired. On the other hand, it provides a practical location for commuters to meet up as hubs are typically located in well-accessible areas. Having such facilities at the hub can increase the attractiveness of the hub to commuters. It might also reduce the number of trips when people only have to travel to the hub instead of the office, which can be less accessible and/or further away. The NS (the Dutch railway organization)

already successfully provides meeting spaces to their (international) travelers at Amsterdam and Rotterdam station.

Status quo attributes

As indicated in Table 5, the status quo alternative is described by two attributes: the travel distance from origin to destination by car and parking costs at the destination. Additionally, the price of the trip is presented, but it is not included as an attribute in the design. To improve the realism of the trip's price, the price is calculated considering the fuel costs, which is determined by the fuel type of the respondent's private. At the start of the survey, respondents are asked to indicate the type of fuel their car utilizes, allowing for adjustments in the price of the trip accordingly. The fuel types included in the research are diesel, gasoline, LPG, electric, hybrid, and plug-in hybrid.

Travel distance from origin to destination by car (OD)

This variable indicates the travel distance from the origin to the destination by private car. A distinction is made between the urban and regional hub as it is assumed that the latter involves larger distances. Four levels (per hub) are used for this attribute.

In the context of the urban hub, the minimum and maximum travel distance range is determined in the following way. The minimum distance between origin and destination by car should be higher than the maximum distance from origin to hub. This criterion ensures that traveling through the hub may represent a feasible option as it cannot be expected that one will travel via the hub if it is already located further than the original destination. The maximum distance between origin and hub in the urban area is set to 2 kilometers. Therefore, it is decided that the minimum distance between origin to destination by car is 3 kilometers. The maximum travel distance is based on the maximum travel distances one can encounter in Amsterdam, the largest city in the Netherlands, which is 15 kilometers. This means that the range is between 3 and 15 kilometers. The other two levels are equally distanced and placed in between this range (i.e., 7 and 11 km).

The attribute levels are chosen differently for the regional hub. The average travel distance that most people cover for traveling to work is considered to determine these levels. This travel distance is usually between 15 and 35 kilometers and, on average, 23 kilometers (CBS, 2018). Therefore, the four levels are set to 10, 25, 40, and 55 kilometers.

While this attribute appears as the total kilometers to be traveled in the description of the context of the question, it is also transformed to travel time by car (in minutes). The total travel time by car is calculated by using the average speed of the car. This average speed differs based on the distance. Appendix A shows the average speed used for different distance ranges.

Parking costs for the status quo trip

When traveling by car, the vehicle should be parked somewhere, which is often associated with costs. Therefore, eight different levels are included, from (relatively) cheap (0-8 euros) to more expensive parking costs (20-28 euros). Parking prices are presented as a fixed number rather than €/hour, because, in the latter case, another attribute regarding the duration of the activity (and duration which the car is parked) must also be added, which would complicate the matter. The price of parking, especially in cities, fluctuates a lot. In Utrecht, the price can be up to 40 euros (in Amsterdam even 60 euros) a day, while the minimum price per day lies around 10 euros. The decision to assign eight levels to this attribute was motivated by such heterogeneity.

Mobility hub attributes

Distance from origin to the hub (OH)

This attribute determines the distance from the origin to the hub. This attribute differentiates between the urban and regional hub.

In the urban hub, shorter distances are assumed, allowing active transport modes to access the hub. The literature review showed that people are willing to walk to a transit stop between 500 and 1000 meters (Mo et al., 2018; Stanesby et al., 2021). Therefore, for the urban hub, two levels are chosen which can be covered by walking, while two levels exceed this critical distance but remain within a 10-minute cycling range. More precisely, distances of 0.5, 1.0, 1.5, and 2.0 kilometers are chosen as attribute levels.

Regional areas are less dense. Therefore, the distance from origin to hub is expected to be larger than in urban areas. As the distance between origin and destination can also be larger and varies more than in the urban area, another approach is chosen to determine the attribute levels. The levels for the distance from origin to the hub in the regional area will be determined by a percentage of the original distance from origin to destination. The levels are set at 30%, 40%, 50%, and 60%.

Parking costs at the hub

Parking costs should be kept at a reasonable level, ensuring that the hub is an attractive option for travelers. High parking fees can discourage travelers from using the hub. In order to determine a viable parking scheme for parking at the hub, P+R prices are considered as basis as this is also a location for travelers to park their cars during the day.

In many P+R areas, parking is free of charge (NS, n.d.). For example, the municipality of Rotterdam implemented a regulation that allows free parking at P+R facilities when users continue their trips by public transport. However, this is not always the case, and fees ranging from 1 to 8 euros per 24 hours also occur (Parkeren in de Stad, n.d.).

Two pricing levels for parking at the hub are chosen for this study. The first level is where parking is free parking, and the second is where a fixed fee of 8 euros is charged for parking private cars at the hub.

Transfer time

The transfer time is defined as the duration it takes for travelers to walk from their parked vehicle (such as car, bike, scooter) to their desired mode of transportation after arriving at the hub. The transfer times are 1, 3, 5, and 7 minutes. The 7-minute transfer time corresponds to a large hub, while one minute corresponds to a small hub.

Utrecht Central Station is used as a reference point. Walking from one side of this station to the other side takes 7 minutes. As Utrecht Central Station is the largest train station in the Netherlands, it is reasonable to assume that mobility hubs will not exceed this.

Facilities and services

Facilities and services are also presented in the experiment as being part of the hub. In total, seven facilities are included. Four of the facilities are based on secondary travel purposes. The other facilities are chosen based on what large(r) train stations offer and four informal interviews (with three frequent car drivers and one frequent public transport user). In short, the facilities entail the following:

- *Supermarket:* A normal-sized supermarket for daily groceries. This facility is connected to the attribute level *grocery shopping* of the attribute *other activities.*

- *Parcel pick-up point:* A parcel machine where parcels can be delivered and picked up. This facility is connected to the attribute level *picking up a parcel* of the attribute *other activities.*
- *Café:* A location where one can sit, read a book, drink a cup of coffee, eat something, or meet up with colleagues, for example.
- *Gym:* As the name implies, it is a space for physical exercise. This should reduce the effort of traveling and, thus, reduce the number of trips. 3.3 million Dutch people are subscribed to a gym (Kennisbank Sport en Bewegen, 2018).
- *Drugstore and medicine pick-up point:* A regular drugstore for medicine and care products. It can also be convenient to be able to pick up one's medicines at a location where one would already come.
- *Daycare:* As mentioned, in other countries, offering daycare near public transport is common (Carmo, 2020). Therefore, this could also be a convenient facility in the Netherlands. This facility is connected to the attribute level *picking up and dropping off children from daycare* of the attribute *other activities.*
- *Social extended reality office:* This is a new concept and entails an advanced way of digital meetings. One can have lifelike meetings with colleagues or customers sitting at the same table with them while not being physically there. This is possible through special XR glasses (Niamut, 2021). This facility is connected to the attribute level *business meeting* of the attribute *other activities.*

For some of the facilities, the respondents were shown an image of the facility to be able to picture the concept. In each choice set, it is indicated whether the facility is available or not.

Transportation mode attributes

At the hub, four transportation modes are offered. Four transport modes are included for the urban hub: the bus, shared bike, shared scooter, and shared car. The same transport modes are included in the regional hub, except for the bus, which is replaced by train. The train is included as longer distances are typically covered using regional hubs. Although the bus could also be kept in the regional hub, it is decided to limit the available modes to four modes in each type of hub to manage the complexity of the design (of the survey) and the mental burden of respondents in trading off between many alternatives.

The shared car is based on a station-based system. The car should be picked up and parked at specific spots as this fits the hub idea better than the free-floating system. Moreover, the shared bike and scooter are both based on a free-floating system, as this aligns with how most shared scooter and bike operators currently work. The bikes and scooters can be parked at flexible (but often still designated) locations.

Tariff per kilometer

Price is essential for choosing travel modes (Ilahi et al., 2019; J. Le & Teng, 2023). Therefore, the tariff per kilometer for each transport mode included in the hub is assigned based on desk research to ensure realism. The prices for the bus, train, shared bike, and shared scooter can easily be found by consulting current operators of these transport modes. The shared car, however, does not have a clear fixed price per kilometer as the price is dependent on many factors such as distance, speed, and time. The kilometer price is calculated based on checking several trips, with distances varying from short to long on the operators' websites.

After determining the market prices per kilometer, four levels are created around the market price to determine the influence of price on hub use. More precisely, the levels for each mode are as follows:

- Bus: 0.13/0.17/0.21/0.25 (€/km).
- Train: 0.15/0.2/0.25/0.30 (€/km).
- Shared e-scooter: 0.5/0.65/0.8/0.95 (€/km).
- Shared e-bike: 0.4/0.5/0.6/0.7 (€/km).
- Shared car: 0.51/0.66/0.81/0.96 (€/km).

It is important to note that the respondents see the final price (€/km * distance to be covered) instead of the price per kilometer. In this way, it is easier for respondents to compare the price.

Travel distance from hub to destination (HD)

Three factors are considered when determining the travel distance from the hub to the destination (HD). First of all, the travel distance from the origin to destination (OD) using the private car is taken. Secondly, the distance from origin to the hub (OH) is considered and subtracted from this total distance (OD). Thirdly, a multiplication factor (MF) is included in the formula. This multiplication factor determines whether the hub is, for example, in the right direction to the destination or it is (slightly) out of the direction. The multiplication factor differentiates from 0.80 to 1.40 with an interval of 0.2. A value of 0.80 means that one travels a shorter distance via the hub. A multiplication factor of 1.40 indicates a longer distance. Both scenarios are within a somewhat realistic range. In Figure 8, the travel situation is visualized, including the distances that should be covered.

Arrival frequency of offered transport modes

For determining the arrival frequency of public transportation, the critical waiting time is taken into account. The critical waiting time for the bus and shared car are estimated to be respectively 15 and 8 minutes (Roy & Basu, 2021). However, when amenities are offered at the hub, it could be beneficial (or less annoying) to have a longer waiting time.

Based on this, the following arrival frequencies per hour are chosen. The bus and train are assumed to arrive two times per hour or four times per hour. The latter meets the critical waiting time as passengers do not have to wait more than 15 minutes. A frequency level of 2 times per hour (so every 30 minutes) exceeds this critical waiting time. However, as facilities are offered, this might not be a problem. Furthermore, it is assumed that other transport modes are always available.

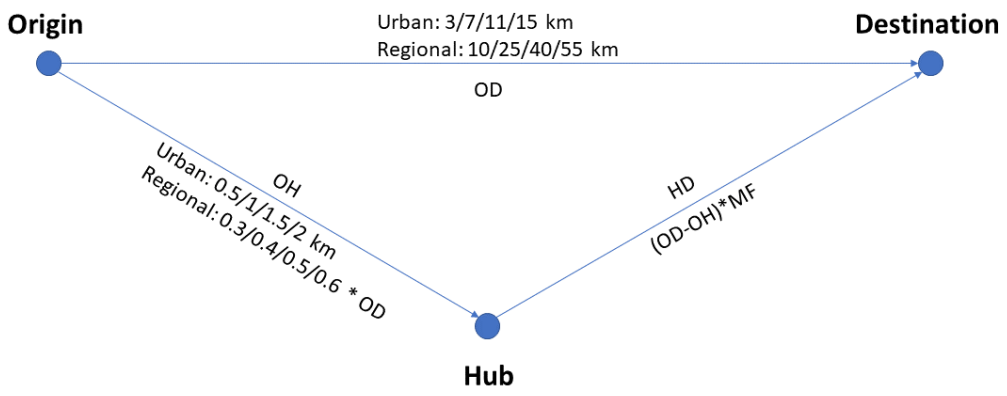

Figure 8 Travel situations

3.2.1.3 Stage 3-7: Experimental design

As described in the previous section, eventually 11 attributes of two levels, 9 attributes of four levels, and 1 attribute of eight levels are used in designing the stated choice experiment. A total of $2^{11} * 4^9 * 8^1 = 3*10^{10}$ (30 billion) choice sets should be presented for a full factorial design. In such a design, all possible combinations of attribute levels are included (Hensher et al., 2015b). Obviously, a full factorial design is unrealistic and the number of choice sets should be reduced. Hensher et al. (2015) propose four ways in which this can be done. The first way is to reduce the number of attribute levels. This however also reduces the information that is collected. As it is undesired to have only two levels because of the always linear relationship, most attributes have four levels. If possible, it is tried to keep the number of levels as they were as much as possible. The second way is to use a fractional factorial design in which, as the name already indicates, only a fraction of all attribute-level combinations is used in the design. To create a fractional factorial design, attention should be paid to orthogonality, an important mathematical concept. It means that independency between the attributes is important. In practice, it implies no correlations between the attributes and each possible set of attribute levels is presented the same number of times throughout the design. The third way is blocking the design. This means that the design is segmented into different blocks. For example, when the design has 36 choice sets, this can be divided into four blocks of nine choice sets; the respondents see only one block of 9 choice sets. The cognitive burden for the respondents reduces, improving the reliability of the answers. However, also more respondents are required (Hensher et al., 2015b). The fourth way to reduce the number of choice sets is by combining the second and third way (fractional factorial design and blocking). This last approach is used in this research.

SAS software is used for creating the fractional factorial experimental design. The commands used in SAS are presented in Figure 9. The first command (%Mktruns()) decides the number of reasonable runs in the design. The results show two orthogonal design sizes of 64 and 128. The higher the number of runs, the more respondents are required. Therefore, a reasonable design size is set to N=64. The second command (%Mktex()) helps to create an efficient factorial design with the chosen design size. A seed number of 120 is used. This is a random number and also presents a random stream of numbers resulting in a particular output. The third command (%Mkteval()) is to evaluate the design with a randomized dataset on its balance and orthogonality. After that, the design should create blocks because the design is too large for one respondent. Blocking is possible in several ways. Often, a specific block macro (%Mktblock) is used. However, in this case, creating a design without correlations with this macro is not possible. Therefore, an alternative macro is used, %Mktlab. This macro mainly serves to rename factors. In this case, an extra factor, a block factor, is added of eight levels for the eight blocks that should be created. The macro distinguishes the blocking factor from the design factors. In Appendix B, the output of SAS is presented. As can be seen, no correlations appear between the variables and blocks. Also, all attribute levels appear with similar frequencies.

```
%Mktruns(2**11 4**9 8**2, options=source);
%Mktex(2**11 4**9 8**2, N=64, seed=120);
%Mkteval(data=randomized);
%Mktlab(data=randomized, vars=x1-x21 Block);
proc print; run;
```

Figure 9 Commands SAS

3.2.1.4 Stage 8: Survey construction

The survey is constructed in LimeSurvey. The stated choice experiment consists of eight blocks with each eight questions. As there is a difference between the urban and regional hub, the numbering of the blocks is changed. For example, block 1 is now block 1-1 for the urban hub and 2-1 for the regional

hub. The same experimental design is thus used for both the urban and regional hubs as the hubs have the same number of attributes and attribute levels. Each respondent gets assigned to one of the eight blocks for the urban or regional hub. All questions besides the stated choice experiment are the same for everyone. The setup of the survey is already discussed in section 3.1.

Below, example SC questions for the urban hub (Figure 10) and regional hub (Figure 11) are presented. In the yellow box, the context of the trip is described. On the blue side is the status quo, and on the green side is the mobility hub. In Appendix E, the final survey is presented.

*

You need to travel 7 km for work while it is raining. You also have to do the groceries that day. Would you travel by your own car or via the hub?						
Situation 1: Trip by own car		**Situation 2: Traveling via the hub**				
Travel time	19 minutes	Distance from home to hub	2 km			
Parking costs	€20	Parking costs if you park your car at the hub	€8			
Fuel costs	€2,31	Transfer time to get to transporta-tio mode	7 minutes			
Private car		**Available transport modes**	**Bus**	**Shared e-bike**	**Shared e-scooter**	**Shared car**
		Travel time from hub to destination	12 minutes	14 minutes	14 minutes	10 minutes
		Costs for the trip	€3,35	€3,51	€3,51	€5,55
		Arrival requency per hour	4	Always available	Always available	Always available
		Facilities at the hub			**Available (✓) or not available (-)**	
		Supermarket			✓	
		Parcel pick-up point			✓	
		Café			-	
		Gym			✓	
		Drugstore and medicine pick-up point			✓	
		Social extended reality office			✓	
		Daycare			✓	
○		○				

Figure 10 Example question urban hub

*

You need to travel 40 km for work while the sun is shining. You also have an online meeting that day. Would you travel by your own car or via the hub?						
Situation 1: Trip by own car		**Situation 2: Traveling via the hub**				
Travel time	28 minutes	Distance from home to hub	12 km			
Parking costs	€24	Parking costs	€8			
Fuel costs	€5.30	Transfer time to get to transporta-tion mode	7 minutes			
Private car		**Available transport modes**	**Train**	**Shared e-bike**	**Shared e-scooter**	**Shared car**
		Travel time from hub to destination	21 minutes	102 minutes	102 minutes	28 minutes
		Costs for the trip	€8,38	€16,69	€38,25	€34,75
		Arrival frequency per hour	4	Always available	Always available	Always available
		Facilities at the hub			**Available (✓) or not available (-)**	
		Supermarket			-	
		Parcel pick-up point			-	
		Café			-	
		Gym			-	
		Drugstore and medicine pick-up point			-	
		Social extended reality office			✓	
		Daycare			-	
○		○				

Figure 11 Example question regional hub

3.3 Conclusion

This chapter described the research design for this study. The identification of attributes and attribute levels are described as well as the creation of an efficient factorial design. In the SC experiment, the

decision-makers had to choose between the private car and the urban or regional mobility hub. Within the stated choice experiment, a stated choice (sub-)experiment is included for transportation mode choice. Finally, two example SC questions were presented.

4 Data collection, preparation, and sample description

4.1 Data collection

The survey was distributed among people living in the Netherlands in the first two weeks of March 2023. The survey was first distributed among 50 respondents to check for malfunctions and how the output of the survey data would look. No problems occurred and the survey was fully distributed. The recruitment of respondents was done in two ways. The survey was distributed across the researcher's network via e-mail and WhatsApp. In addition, a marketing research firm specializing in distributing surveys concerning various topics was used for distribution. Eventually, a total of 2049 people opened the survey. In section 4.2, data preparation is further elaborated.

4.2 Data preparation

A total of 2049 respondents filled in the survey of which 1512 could pass the filtering questions (i.e., ownership of a driver's license, driving the car at least once a week, and owning at least one car). 398 respondents were removed from the sample because they quit the survey before the end, and another 168 respondents were removed from the sample because the total response time was less than 5 minutes. Lastly, 22 respondents were excluded from the analysis because their responses to seven attitudinal statements and seven facility statements were identical. Eventually, 924 respondents were used for the subsequent analyses. Table 6 summarizes the procedure of data cleaning.

Table 6 Filter criteria

Action	**Number of responses left**	**Number of removed respondents**
Start number	2049	
Removal after filter requirements	1512	537
Removal because the survey was not completed	1114	398
Removal when total time to fill in the survey was less than 5 minutes	946	168
Removal in case of equal answers for Likert scale questions	924	22
Final number of respondents	924	

After filtering the data, four data sets were prepared. The first two data sets were used for investigating the choice between the multimodal mobility hub and the private car in the urban (data set 1) and regional setting (data set 2), so this covered RQ1 and RQ2. The other two data sets were used for investigating the choice of transportation modes at the urban (dataset 3) and regional (dataset 4) hub, so this covered RQ3.

In the survey, all respondents were randomly assigned to one of the eight blocks for the urban or regional hub. Figure 12 shows the number of respondents per block for the choice between car and hub (dataset 1 and 2). The figure presents a reasonable sample size for each block without large differences between the blocks.

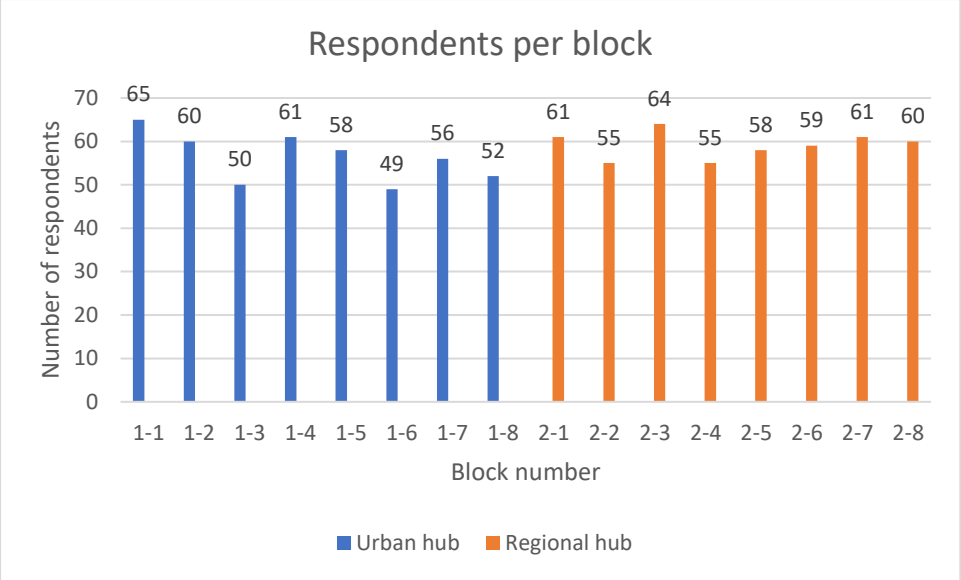

Figure 12 Number of respondents per block (choice between hub and car)

Figure 13 presents the number of observations per block for transportation mode choice (datasets 3 and 4). The total number of observations for transportation mode choice is lower than the number of observations for hub choice. 1900 observations were included for the transportation mode choice (compared to 7392 observations for the choice between hub and car). Of these 1900 observations, 1099 were for the urban mobility hub and 801 were for the regional mobility hub. The number of observations for transportation mode choice is lower because only if respondents chose to use the hub, they were asked to choose between transportation modes. In 25.7% (1900/7392) of the choice tasks, respondents chose the mobility hub and, thus, had to choose a transportation mode.

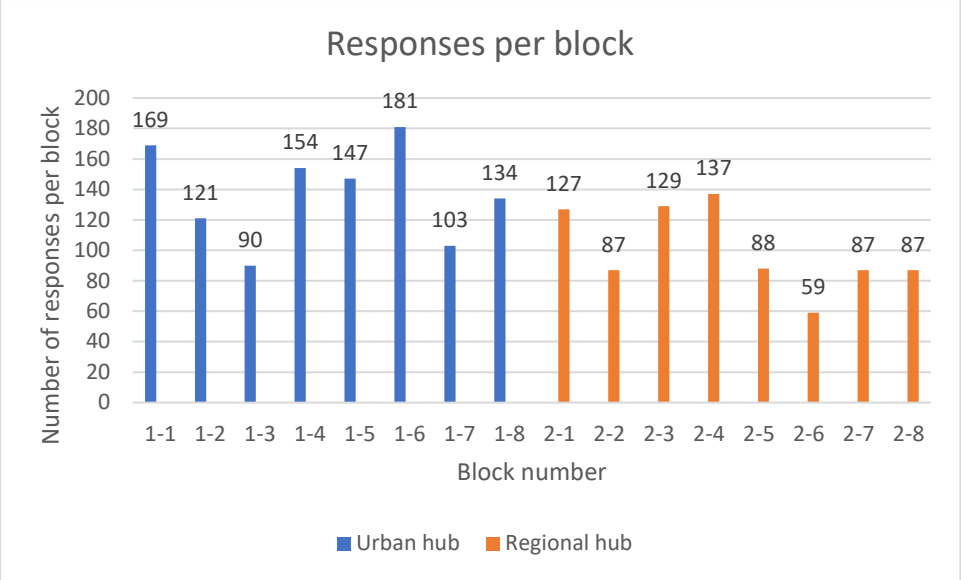

Figure 13 Number of responses per block (transportation mode choice)

4.3 Sample characteristics

Table 7 presents the frequency distribution of the sample. When available, national statistics are listed in the last column for comparison and illustration of the sample's representativeness. When comparing the sample statistics with national statistics, it should be noted that this sample consists of car owners and drivers. Some differences between the statistics can be explained because of that.

The sample consists of 924 respondents who all possess a driver's license, own a car, and are frequent drivers (i.e., drive a car at least once a week). The sample is represented by an almost equal share of men (51.9%) and women (48.1%) which is in line with the Dutch population statistics. The distribution of age deviates from the overall Dutch population statistics. The age group of 18-34 years old is underrepresented, while the group of 55-64 years old is overrepresented. This discrepancy can be attributed to the requirement that all respondents had to own a driver's license and a car, which is less likely among younger people (CBS, 2021b). Respondents with a lower income and education are also underrepresented in the sample, likely due to the same reason (J. Witte et al., 2022). Moreover, the percentage of working people in the sample (77.8%) is comparable to the overall employment rate in the Netherlands (73%). Also, household composition percentages are comparable with Dutch population statistics; 39.4% of the households is with children and 60.6% of the households is without children.

As this research conducts separate analyses for the urban and regional hub, Table 7 presents the statistics of these data sets separately as well. The sample size consists of 451 respondents for the urban hub and 473 respondents for the regional hub. There are no substantial differences in the sample distribution between the two data sets.

Table 7 Socio-demographics characteristics

Variable		All (n=924)	%	Urban data (n=451)	%	Regional data (n=473)	%	Netherlands %
Gender	Male	480	51.9%	245	54.3%	235	49.7%	49.7%
	Female	444	48.1%	206	45.7%	238	50.3%	50.3%
Age	18-34 years	113	12.2%	17	14.0%	50	10.6%	27.8%
	35-54 years	343	37.1%	70	36.8%	177	37.4%	36.8%
	55-64 years	247	26.7%	113	25.1%	134	28.3%	11.6%
	65 and older	221	23.9%	86	24.2%	112	23.7%	25%
Montly net income	Low	135	14.6%	64	14.2%	71	15.0%	38.4%
	Middle	553	59.8%	275	61.0%	278	58.8%	43.2%
	High	81	8.8%	34	7.5%	47	9.9%	18.5%
	No information	155	16.8%	78	17.3%	77	16.3%	-
Employment status	Working	719	77.8%	349	77.4%	370	78.2%	73%
	Not working	205	22.2%	102	22.6%	103	21.8%	27%
Education	Low	113	12.2%	56	12.4%	57	12.1%	25.8%
	Middle	376	40.7%	182	40.4%	194	41.0%	38.1%
	High	435	47.1%	213	47.2%	222	46.9%	35.5%
OV chipcard ownership	Yes, with subscription	205	22.2%	100	22.2%	105	22.2%	-
	Yes, without subscription	282	30.5%	138	30.6%	144	30.4%	-
	No	437	47.3%	213	47.2%	224	47.4%	-
Household	Household with children	364	39.4%	170	37.7%	159	33.6%	29.0%
	Household without children	560	60.6%	281	62.3%	314	66.4%	71.0%

Table 8 presents the sample characteristics in terms of use and ownership of the car. As can be seen, 43.9% of the sample drives a car five days per week or more. This percentage is almost similar for the urban and regional data. Furthermore, the collected data reveal that the majority of the sample (60.0%) uses the car as a passenger less than once a week. This seems logical considering that if individuals are frequently driving the car, they are less likely to be car passengers. Moreover, most respondents (66.1%) own one car, which is equal to the average in the Netherlands (CBS, 2021a). Only 51 respondents (9.6%) indicated having three or more cars. Also, questions were asked about the type of ownership and fuel type of respondents' most used car. 94.4% of the respondents possess a private car and 78.9% a gasoline-car. Again, there were no substantial differences in the sample distribution between the two data sets.

Table 8 Characteristics use and ownership of the car

Variable		All (n=924)	%	Urban data (n=451)	%	Regional data (n=473)	%
How often do you use the car as driver?	1-2 days per week	240	26.0%	112	24.8%	128	27.1%
	3-4 days per week	278	30.1%	132	29.3%	146	30.9%
	5 days per or more	406	43.9%	207	45.9%	199	42.1%
How often do you use the car as passenger?	Less than once a week	554	60.0%	273	60.5%	281	59.4%
	1-2 days per week	275	29.8%	136	30.2%	139	29.4%
	3 days per week or more	95	10.3%	42	9.3%	53	11.2%
Nr. of private cars in household	1	611	66.1%	299	66.3%	312	66.0%
	2	262	28.4%	127	28.2%	135	28.5%
	3 or more	51	5.5%	25	5.5%	26	5.5%
Ownership type	Private car	872	94.4%	422	93.6%	450	95.1%
	Lease car from work	52	5.6%	29	6.4%	23	4.9%
Fuel type of the car	Gasoline	729	78.9%	352	78.0%	377	79.7%
	Diesel	77	8.3%	42	9.3%	35	7.4%
	Electric	31	3.4%	16	3.5%	15	3.2%
	Hybrid	65	7.0%	27	6.0%	38	8.0%
	Plug-in hybrid	14	1.5%	10	2.2%	4	0.8%
	LPG	8	0.9%	4	0.9%	4	0.8%

Table 9 presents the statistics regarding respondents' familiarity with three types of shared transportation modes. It shows that most respondents are unfamiliar or do not use these shared transportation modes.

Table 9 Familiarity with shared mobility modes

Variable		All (n=924)	%	Urban data	%	Rural data (n=473)	%
Familiar with shared (e-)bike	Yes, and I use it	59	6.4%	31	6.9%	28	5.9%
	Yes, but I do not use it	476	51.5%	239	53.0%	237	50.1%
	No	389	42.1%	181	40.1%	208	44.0%
Familiar with shared (e-)scooter	Yes, and I use it	43	4.7%	22	4.9%	21	4.4%
	Yes, but I do not use it	538	58.2%	271	60.1%	267	56.4%
	No	343	37.1%	158	35.0%	185	39.2%
Familiar with shared car	Yes, and I use it	30	3.3%	15	3.3%	15	3.2%
	Yes, but I do not use it	599	64.8%	294	65.2%	305	64.5%
	No	295	31.9%	142	31.5%	153	32.3%

5 Data analysis and results

This chapter explains the theory behind data analysis of the stated choice experiment data.

5.1 Method

5.1.1 Random utility theory

The random utility theory assumes that decision-maker *n* derives a particular utility, U_{ni}, from alternative *i*. When making a choice between multiple alternatives, the decision-maker chooses the alternative with the highest utility level. Not all decision-makers choose the same alternative, as there can be taste differences between individuals and within individuals. Moreover, following the random utility theory, the decision-maker looks at the alternative as a whole while the researcher looks at the attributes of the alternative. These attributes have a particular utility level with which the total utility of an alternative can be estimated. The utility of alternative *i* for respondent *n* can be determined as follows:

$$U_{in} = V_{in} + \varepsilon_{in} \quad (1)$$

In equation 1, two components can be distinguished. The first component, V_{in}, is the (observed) structural utility and the second component, ε_{in}, is the random utility or the error term. The random utility represents the utility that the structural utility cannot capture. It represents the heterogeneity and measurement errors. Besides, the random utility follows some statistical distribution that the researcher can specify.

The structural utility can be estimated as follows:

$$V_i = \sum_k \beta_k X_{ik} \quad (2)$$

In equation 2, X_{ik} represents the value of attribute *k* of alternative *i*, and β_k is the parameter to be estimated, representing the effect of attribute *k* on alternative *i*. Finally, following these equations, the probability that alternative *i* will be chosen can be calculated (Train, 2003).

5.1.2 Multinomial logit model

The multinomial logit (MNL) model can estimate these utility levels. This model assumes that the random term follows a Gumbel distribution and is independent (Hensher et al., 2015c; Train, 2003). The MNL model is the most widely used model for discrete choice modeling and can identify decision-makers' preferences in a choice situation. This model is commonly used in transportation research and is applied to topics such as mode choice (Hensher et al., 2015a). The model is relatively easy to estimate but encounters some limitations. Probably the greatest limitation is the Independence from Irrelevant Alternatives (IIA) property (Kemperman, 2000). This limitation is derived from the assumption that the error term is identically and independently distributed and that there is independency between the alternatives. It assumes that there are no correlations between the random components and that the statistical distributions of these components are similar (Train, 2003). In practice, it means, for example, that if a decision-maker chooses between two alternatives, the IIA property assumes that the ratio between these two alternatives stays the same when adding a third ("irrelevant") alternative.

5.1.3 Mixed logit model

The limitations of the MNL model because of the IIA property can be solved by using a mixed logit (MXL) model. In the MXL model, the random terms have an alternative distribution; the most used distributions are the normal, log-normal, triangular, and uniform distribution(Train, 2003). In addition, the MXL model does not assume that the error terms are independent and have an identical variance.

Therefore, the model can incorporate the similarities between the alternatives, taste differences, and panel effects. In this thesis, the random parameter mixed logit model with panel effect is applied, which measures whether heterogeneity (i.e., variance) exists in parameters associated with the attributes. It thus allows for identifying taste differences. The higher the standard deviation of the random parameter, the more heterogeneous the responses are regarding the importance they attach to the associated attribute.

5.1.4 Goodness of fit

To find out the model performance and to what extent the model fits the data, the goodness of fit can be estimated using McFadden's Rho-Square with the following formula:

$$R^2 = 1 - \frac{LL(\beta)}{LL(0)} \quad (3)$$

In equation 3, LL(β) is the log-likelihood using the estimated parameters. This number is based on estimations made separately for each individual choice. LL(0) is the log-likelihood when using the null-model. It means that all alternatives have the same probability of being chosen. LL(β) is calculated by the software (Nlogit). LL(0) is calculated via the following formula, with P_{ni} being the probability that alternative i will be chosen by individual n:

$$LL(0) = \sum_{n=1}^{N} \sum_{i} ln\,(P_{ni}) \quad (4)$$

Besides the R-squared, the adjusted R-squared is estimated. This is because the R-squared often has a too high value (Karch, 2020). The more independent variables are included in the model, the higher the R-squared is, independent of whether the variables really improve the model. The adjusted R-squared deals with this limitation by considering the number of independent variables. The adjusted R-squared can determine whether new independent variables improve the goodness of fit. The following equation is used to calculate the adjusted R-squared, with d being the number of observations and k the number of independent variables in the dataset:

$$R^2_{adjusted} = 1 - \frac{(1-R^2)*(d-1)}{d-k-1} \quad (5)$$

Higher values are generally preferred for both R-squared and adjusted R-squared. If the value of the R-squared and the adjusted R-squared are above 0.2, it can be concluded that the model fits the data reasonably well (Train, 2003).

5.1.5 Main and interaction effects

In this thesis, main effects and interaction effects are estimated. Main effects concern the direct effect of independent variables (attributes) on the dependent variable (the choice). With an interaction effect, two or more variables are combined through multiplication and their combined effect on the dependent variable is examined. In this way, a two-way (or three-way, four-way, etc.) interaction term can be estimated. The interaction effect is used when it is expected that a certain combination of two (or more) attributes have a significant effect on the dependent variable beyond their respective effect (Hensher et al., 2015b).

5.1.6 Analysis software

Two software programs are used to perform the analyses. IBM SPSS Statistics 27 is used for descriptive analyses and Nlogit6 is used to conduct the MNL and mixed logit regression analyses. The codes that are used in Nlogit can be found in Appendix C.

5.2 Choice between private car and mobility hub: model results

This section describes the results of the MNL and MXL analysis for the urban and regional hub. Effect coding is used for the variables to be able to conduct these analyses. The section includes a short interpretation of the unexpected results. Chapter 0 compares results to previous research and elaborates on implications.

5.2.1 Model results for the urban mobility hub

The model results for the hub choice in the urban area are presented in Table 10. Firstly, the MNL model results are discussed. After that, the MXL model results are discussed.

As a note, in the left column of the table, hub or status quo is written. This indicates if the coefficient increases or decreases the utility of the hub or the status quo.

Table 10 Results MNL and MXL model for the choice between private car and urban hub

			Coefficients and standard error urban hub choice			
	Variable	**Variable levels**	**MNL coefficients**	**St. error**	**MXL coefficients**	**St. error**
HUB	**Constant**		-2.134***	0.147	-3.705***	0.402
	Weather	Sun	0.224***	0.040	0.387***	0.066
		Rain	-0.224		-0.387	
	Primary travel purpose	Work	-0.03	0.040	-0.046	0.062
		Leisure	0.03		0.046	
	Other activities	Grocery shopping	-0.01	0.070	0.027	0.094
		Picking up a package	0.06	0.069	0.093	0.102
		Business meeting	0.331***	0.068	0.553***	0.112
		Bringing and picking up children from daycare	-0.381		-0.673	
	Travel distance origin-hub	0.5 kilometer	0.049	0.070	0.092	0.097
		1 kilometer	-0.017	0.071	0.014	0.097
		1.5 kilometer	-0.046	0.071	-0.073	0.097
		2 kilometer	0.014		-0.033	
	Transfer time	1 minute	0.053	0.069	0.078	0.096
		3 minutes	-0.017	0.071	-0.063	0.099
		5 minutes	0.054	0.070	0.100	0.099
		7 minutes	-0.09		-0.115	
	Parking price at the hub	0 euros	0.157***	0.040	0.232***	0.061
		8 euros	-0.157		-0.232	
	Supermarket	Yes	0.005	0.041	0.016	0.060
		No	-0.005		-0.016	
	Parcel pick-up point	Yes	0.04	0.041	0.045	0.055
		No	-0.04		-0.045	
	Café	Yes	-0.014	0.040	-0.030	0.062
		No	0.014		0.030	
	Daycare	Yes	0.01	0.040	0.022	0.062

		No	-0.01		-0.022	
	Gym	Yes	0.017	0.040	0.041	0.054
		No	-0.017		-0.041	
	Drug store/medicine pick-up point	Yes	-0.018	0.040	-0.032	0.055
		No	0.018		0.032	
	Social extended reality office space	Yes	0.129***	0.041	0.192***	0.061
		No	-0.129		-0.192	
	Parking price for the status quo		-0.057***	0.005	-0.099***	0.008
STATUS QUO	**Distance from origin to destination by private car**	3/10 kilometer	-0.494***	0.067	-0.778***	0.104
		7/25 kilometer	-0.045	0.070	-0.07	0.104
		11/40 kilometer	0.094	0.071	0.13	0.108
		15/55 kilometer	0.008		0.655	
	Gender	Male	0.025	0.045	0.058	0.129
		Female	-0.025		-0.058	
	Age	18-34 years	0.042	0.098	0.260	0.308
		35-54 years	0.144**	0.072	0.306	0.213
		55-64 years	-0.234***	0.077	-0.602**	0.236
		65 years and older	0.048		0.036	
	Income	Low	-0.301***	0.106	-0.87***	0.312
		Middle	0.044	0.066	0.016	0.190
		High	0.08	0.132	0.505	0.342
		No information	0.177		0.349	
	Education	Low	-0.562***	0.100	-0.719***	0.260
		Middle	0.403***	0.067	0.696***	0.183
		High	0.159		0.023	
	Employment status	Working	0.102**	0.047	0.134	0.140
HUB		Non-working	-0.102		-0.134	
	Household	With kids	0.111**	0.048	0.202	0.145
		Without kids	-0.111		-0.202	
	Number of cars in the household	1 car	0.366***	0.084	0.870***	0.278
		2 cars	0.012	0.087	0.288	0.263
		3 cars or more	-0.378		-1.158	
	#Driving a car per week	1-2 days a week	0.358***	0.064	0.698***	0.212
		3-4 days a week	0.096*	0.058	0.242	0.174
		5 days a week or more	-0.454		-0.940	
	#As passenger in the car	Less than one day per week	-0.493***	0.064	-0.905***	0.188
		1-2 days per week	0.290***	0.060	0.430**	0.181
		3 days per week or more	0.203		0.475	
		Private car	0.167*	0.089	0.214	0.231

Ownership of the car	Lease car from work	-0.167		-0.214	
OV-card ownership	With subscription	0.361***	0.069	0.708***	0.205
	Without subscription	-0.011	0.059	0.056	0.173
	No card	-0.351		-0.764	
Familiarity with shared bike	Yes and use it	0.052	0.110	0.220	0.305
	Yes but do not use it	-0.149*	0.068	-0.367*	0.197
	No	0.097		0.147	
Random variable	sd. Constant			2.226***	0.153
	sd. Primary activity - Work			0.539***	0.113
	sd. Other activities - Grocery shopping			0.009	0.279
	sd. Other activities - Picking up a package			0.670***	0.202
	sd. Other activities - Business meeting			1.083***	0.161
Model fit	LL(0)	-2500.9		-2500.9	
	LL(β)	-1879.1		-1594.3	
	R^2	0.249		0.363	
	Adjusted R^2	0.243		0.358	

*Note. *p<.05, **p<.01, ***p<.001.*

MNL model

Table 10 shows that the alternative specific constant in the model for the urban mobility hub is negative and significant (β=-2.13, p<.001), indicating that respondents are more likely to choose the status quo (their private car) than traveling via the multimodal mobility hub. This corresponds to the percentage of respondents who chose the status quo (69.5%) instead of the urban mobility hub (30.5%). Multiple factors significantly influence this choice.

The weather is one of these influential factors. The findings show that individuals are more inclined to travel via the multimodal mobility hub when it is sunny (β=0.22, p<.001). This could be due to the fact that traveling via the hub requires people to be outside more often. Moreover, the probability of choosing the mobility hub increases when respondents should attend a business meeting as a secondary travel purpose (β=0.33, p<.001), although working as a primary activity does not significantly influence the choice between the hub and private car. Also, the presence of a social extended reality office space contributes to the willingness to use the hub (β=0.13, p<.001). This can indicate that travelers recognize the value of using the hub and its facilities on their way for another extra activity (e.g., a business meeting in an office). Furthermore, it is unexpected that the travel distance from the origin to hub does not significantly influence the preference for the car or hub. The relatively short distances to the hub (0.5 to 2 kilometers) could be a reason. When this distance is covered by bike or car, the difference in travel time is only a few minutes. Additionally, the parking price at the hub plays a significant role. When free parking is offered at the hub, people are more likely to travel via the hub (β=0.16, p<.001). Also, parking price in the status quo at the destination is important. Increasing the parking price for the status quo significantly decreases the likelihood of choosing one's own car (β=-0.49, p<.001). Lastly, the distance between the origin and destination plays

a role too. The results show that a shorter distance (3 km) negatively influences the choice for the status quo and thus increases the probability of choosing to travel via the hub (β=-0.49, p<.001).

Besides contextual and alternative specific attributes, individual characteristics influence the choice between the private car and the mobility hub. People who are 35-54 years old are more willing to travel via the mobility hub (β=0.14, p<.01) compared to others, while people between 55 and 64 years old have a significantly lower likelihood of traveling via the hub (β=-0.23, p<.001). Moreover, the level of education significantly contributes to the utility of the multimodal mobility hub. Low-educated people have a strong tendency to choose the status quo (β=-0.56, p<.001), while middle-educated people have the tendency to choose the hub (β=0.40, p<.001). Furthermore, people in households with children (β=0.11, p<.01) or one car (β=0.37, p<.001) are also more likely to travel via the mobility hub. A reason could be the usefulness of an extra transportation mode besides the private car for these people. The number of times driving a car or being a passenger in the car also affects the choice of the hub. Driving the car less frequently (i.e., 1 to 2 days per week) (β=0.36, p<.001) or being a passenger 1 to 2 times per week (β=0.29, p<.001) increases the likelihood of choosing the urban hub while being a passenger less than one day per week decreases the likelihood of choosing the hub (β=-0.49, p<.001). The possession of an OV-card (Dutch public transport card) with a subscription also increases the chance of traveling via the hub (β=0.36, p<.001). Finally, familiarity with shared modes appears to influence the preference for the hub significantly; being familiar with the shared bike but never using it decreases the likelihood of choosing the hub (β=-0.15, p<.05).

Finally, the goodness of fit test shows an adjusted R-squared of 0.24. This indicates a good model fit.

MNL model with interactions

It was attempted to improve the MNL model by adding two-way interaction effects. Multiple combinations of interaction effects were included in the model. The model with the highest goodness of fit is eventually chosen. The final MNL model with interactions includes interactions between income and parking price at the destination for the private car, household composition with the daycare facility, and employment status with the office facility. Other interaction effects that were tested are income and parking price at the hub, age and transfer time, age and distance to the hub, and ownership type of the car and distance from origin to destination. However, all interactions were insignificant. The final MNL model with interactions is included in Appendix D.

MXL model

The final random parameter mixed logit model results from several rounds of estimations. Multiple (combinations of) variables are set as random, and several distributions (i.e., normal, lognormal) for these variables are tested. The alternative specific constant, transfer time, travel distance from origin to destination and to hub, parking price at the hub, parking price at the destination for the private car, primary travel purpose, and other activities were tested as random. The reason to test these variables as random was the hypothesis that people's tastes are heterogeneous regarding these attributes. For instance, some people might find it convenient and efficient to travel via the hub when they must pick up a package, while others might view this as an extra hassle when having to do other activities and travel via the hub. The model with the highest goodness of fit is eventually chosen. Finally, random components are added to the following variables: the constant, primary activity, and other activities. A normal distribution is assumed for all random parameters. This model also includes the panel effect, as respondents made eight repeated choices.

In the following, only the random parameters and the parameters that have a different sign or significance compared to the MNL model are discussed. For most parameters, the interpretation stays similar.

Five personal characteristics (age of 35-54 years old, working, household with kids, driving the car 3-4 times a week, and private car ownership) are insignificant in the MXL model while being significant in the MNL model. A reason could be that these factors are closely related to one of the random variables and that the significance therefore changes. Moreover, the standard deviations of the alternative specific constant (σ=2.23, p<.001), work as a primary activity (σ=0. 56, p<.001), and picking up a package (σ=0.67 p<.001) and a business meeting (σ=1.08, p<.001) as other (secondary) activity are significant. However, the parameter coefficients for work as primary activity and picking up a package as secondary activity were insignificant. This means that these two activities generally do not influence the decision-making between private car and hub, while significant taste variations exist for these variables. The other parameter coefficients (for the alternative specific constant and business meeting as secondary activity) were significant, indicating that these factors affect the choice between hub and private car, and that these coefficients vary across the sampled population. The highness of the standard deviation is also important. The larger the number, the more variation exists within the attribute level.

The MXL model performs better than the MNL model. The adjusted R-squared is 0.36, referring to a good model fit.

5.2.2 Model results for the regional mobility hub

The model results for the hub choice in the regional area are presented in Table 11. The MNL model results are first discussed, after which the MXL model results are discussed.

Table 11 Results MNL and MXL model for the choice between private car and regional hub

		Coefficients and standard error regional hub choice			
Variable	**Variable levels**	**MNL coefficients**	**St. error**	**MXL coefficients**	**St. error**
Constant		-2.245***	0.189	-4.138***	0.559
Weather	Sun	0.165***	0.043	0.244***	0.064
	Rain	-0.165		-0.244	
Primary travel purpose	Work	0.006	0.043	-0.009	0.068
	Leisure	-0.006		0.009	
Other activities	Grocery shopping	0.099	0.073	0.246**	0.110
	Picking up a package	-0.093	0.075	-0.110	0.111
	Business meeting	0.245***	0.072	0.450***	0.113
	Bringing and picking up children from daycare	-0.251		-0.585	
Travel distance origin-hub		-0.001	0.006	-0.012	0.009
Transfer time	1 minute	-0.154**	0.078	-0.262**	0.110
	3 minutes	-0.074	0.079	-0.150	0.112
	5 minutes	0.101	0.077	0.199*	0.112
	7 minutes	0.127		0.213	
Parking price at the hub	0 euros	0.006	0.043	0.031	0.065

	8 euros	-0.006		-0.031	
Supermarket	Yes	0.167***	0.044	0.309***	
	No	-0.167		-0.309	0.069
Parcel pick-up point	Yes	0.017	0.044	0.041	0.060
	No	-0.017		-0.410	
Café	Yes	0.106**	0.043	0.169**	0.068
	No	-0.106		-0.169	
Daycare	Yes	0.004	0.043	-0.039	0.068
	No	-0.004		0.039	
Gym	Yes	0.067	0.043	0.112*	0.059
	No	-0.067		-0.112	
Drug store/medicine pick-up point	Yes	-0.089	0.043	-0.16***	0.059
	No	0.089		0.16	
Social extended reality office space	Yes	0.108**	0.043	0.197***	0.066
	No	-0.108		-0.197	
Parking price for the status quo		-0.051***	0.005	-.090***	0.008
Distance to be covered by own car in status quo	3/10 kilometer	-0.278***	0.072	-0.463***	0.110
	7/25 kilometer	-0.037	0.075	-0.116	0.111
	11/40 kilometer	0.271***	0.079	.491***	0.119
	15/55 kilometer	0.044		0.088	
Gender	Male	-0.05	0.050	-0.073	0.148
	Female	0.05		0.073	
Age	18-34 years	0.134	0.106	0.331	0.374
	35-54 years	0.156**	0.075	0.199	0.261
	55-64 years	-0.231***	0.080	-0.386*	0.229
	65 years and older	-0.059		-0.144	
Income	Low	-0.357***	0.114	-0.592	0.376
	Middle	0.319***	0.072	0.861***	0.222
	High	-0.01	0.125	-0.407	0.365
	No information	0.048		1.860	
Education	Low	-0.059	0.098	-0.021	0.296
	Middle	-0.017	0.069	-0.094	0.218
	High	0.076		0.115	
Employment status	Working	0.117**	0.051	0.270	0.164
	Non-working	-0.117		-0.270	
Household	With kids	-0.062	0.051	-0.138	0.164
	Without kids	0.062		0.138	
Number of cars in the household	1 car	0.142*	0.089	0.038	0.261
	2 cars	-0.251***	0.093	-0.604**	0.251
	3 cars or more	0.109		0.566	
#Driving a car per week	1-2 days a week	0.129*	0.067	0.254	0.217
	3-4 days a week	0.016	0.064	0.111	0.195

	5 days a week or more	-0.016		-0.365	
#As passenger in the car	Less than one day per week	-0.086	0.066	-0.072	0.199
	1-2 days per week	0.135**	0.066	0.088	0.199
	3 days per week or more	-0.049		-0.016	
Ownership of the car	Private car	0.176	0.114	0.655*	0.371
	Lease car from work	-0.176		-0.655	
OV-card ownership	With subscription	0.460***	0.067	1.023***	0.236
	Without subscription	-0.041	0.062	-0.066	0.194
	No card	-0.419		-0.957	
Familiarity with shared bike	Yes and use it	0.437***	0.109	0.840**	0.408
	Yes but do not use it	-0.324***	0.069	-0.6**	0.239
	No	-0.113		-0.24	
Random variable	sd. Constant			2.737***	0.213
	sd. Primary activity - Work			0.569***	0.127
	sd. Other activities - Grocery shopping			0.658***	0.184
	sd. Other activities - Picking up a package			0.575***	0.183
	sd. Other activities - Business meeting			0.748***	0.177
Model fit	LL(0)	-2622.9		-2622.9	
	LL(β)	-1732.4		-1434.9	
	R^2	0.340		0.453	
	Adjusted R^2	0.335		0.449	

*Note. *p<.05, **p<.01, ***p<.001.*

MNL model

The alternative specific constant for the regional mobility hub is significantly negative (β=-2.25, p<.001), which means that people prefer traveling by private car over traveling via the mobility hub. This is in line with the percentage of people choosing the status quo (their private car) (78.8%) over traveling via the regional hub (21.2%). Multiple characteristics influence the utility of the private car and the regional mobility hub.

Sunny weather (β=0.17, p<.001) and having a business meeting as a secondary activity (β=0.25, p<.001) increase the willingness of travelers to travel via the regional mobility hub. Moreover, the availability of a supermarket (β=0.17, p<.001), café (β=0.11, p<.01) and social extended reality office space (β=0.11, p<.01) all positively and significantly add to the utility of the mobility hub. This shows that the willingness to travel via the hub increases when certain facilities are offered and larger distances have to be traveled. The need for facilities is less for shorter distances, as presented in the urban hub results where only the office was significantly positive. Furthermore, a transfer time of 1

minute decreases the likelihood of choosing the hub (β=-0.15, p<.01). This could refer to travelers disliking a smaller mobility hub. In addition, the parking price for the status quo is significantly negative (β=-0.05, p<.001), meaning that people are less likely to travel by private car when the parking price at the destination becomes higher. The distance from origin to destination also plays a significant role in people's choice. For short distances of 10 km, people are less likely to travel by private car (β=-0.28, p<.001). However, increasing the distance increases the likelihood of traveling by private car instead of the hub (β=0.27, p<.001). This shows that the private car is more likely to be used when distances are larger.

Individual characteristics also influence respondents' choices. People between 35 and 54 years old are more likely to use the hub (β=-0.16, p<.01) than average, while people between 55 and 64 years old have a lower likelihood (than average) of traveling via the hub (β=-0.23, p<.001). Moreover, people with a lower income (β=-0.36, p<.001) and 2 cars in the household (β=-0.25, p<.001) are also less inclined to use the mobility hub, while people belonging to a middle-income class (β=0.32, p<001) and owning 1 car (β=0.14, p<.05) are more inclined to use the hub. Additionally, being employed (β=0.12, p<.01), driving the car 1-2 days per week (β=0.13, p<.05), traveling as passenger 1-2 days per week (β=0.14, p<.01), and owning an OV-card with subscription (β=0.46, p<.001) are also favorable for the choice of the hub. Finally, being familiar with the shared bike and using it increases the likelihood of choosing the regional mobility hub (β=0.44, p<.001). At the same time, the tendency decreases when people never used the shared bike (β=-0.32, p<.001).

Lastly, the adjusted R-squared is 0.34 which indicates a good model fit.

MNL model with interactions

This MNL model is also tested with interaction effects. Specifically, after several rounds of estimations, the combined effects of the following variables were included: income and parking price in the status quo, household composition and the availability of daycare, and employment status and availability of social extended reality office space. Other interaction effects that were tested are income and parking price at the hub, age and transfer time, age and distance to the hub, and ownership type of the car and distance from origin to destination. The model with the highest goodness of fit was chosen. However, no effects were found to be significant. Appendix D presents the detailed estimation results.

MXL model

The final MXL model is the result of multiple iterations of estimation. Similar variables as in the urban MXL model are tested as random (alternative specific constant, transfer time, travel distance from origin to destination and to hub, parking price at the hub, parking price at the destination for the private car, primary travel purpose, and other activities). The hypothesis was that variation exists across people's preferences for these variables. For example, it was expected that some people like a larger transfer time because it refers to a larger hub, while others prefer a short transfer time because they do not like to walk. Finally, random components are added to the following variables: the constant, primary activity, and other activities. This gave the highest model performance. A normal distribution is assumed for all random parameters, and the effect of repeated choices (panel effect) is also taken into account.

The random parameters and the parameters that have a different sign or significance compared to the MNL model are discussed. The interpretation of most parameters stays similar.

Six personal characteristics (age of 35-54 years old, low income, working, 1 car in the household, and driving and being a passenger in the car 1-2 days per week) are insignificant in the MXL model while

being significant in the MNL model. Contrary, the ownership of a private car now is significantly positive (β=0.66, p<.05), meaning that people with private cars are more likely to use the hub than people with a car from work.

Besides personal characteristics, several attributes significantly affect the choice between the private car and hub in this mode, which was not the case in the MNL model. First of all, grocery shopping as secondary activity increases the willingness to use the hub (β=0.25, p<.01). As the availability of a supermarket already contributed to the willingness to use the hub, this might imply that when people have to travel larger distances, they seem to find the mobility hub convenient when groceries have to be done. Also, a 5-minute transfer time increases the likelihood of using the hub. A 1-minute transfer time was already significantly negative, showing that people generally prefer a longer distance between the transportation mode of arrival and the chosen transportation mode at the hub. A longer walking distance also refers to a larger mobility hub. Besides that, the availability of a gym (β=0.11, p<.05) increases the likelihood of using the hub, while the availability of a drug store and medicine pick-up point reduces the willingness to travel via the hub (β=-0.16, p<.001). The hub's utility reduction because of the availability of a drugstore is unexpected as people are not obliged to use facilities at the hub.

Furthermore, all standard deviations of the random variables are significant, referring to the existence of heterogeneity. For the alternative specific constant (σ=2.74, p<.001), grocery shopping (σ=0.66, p<.001) and picking up a package as other activity (σ=0.58, p<.001), both the standard deviation and parameter coefficient are significant, meaning that these attribute levels affect the choice between private car and hub while also taste variations exist for these variables. It means that there is considerable variation among individuals in their preferences regarding these variables. Work as a primary activity (σ=0.57, p<.001) and a business meeting as a secondary activity (σ=0.75, p<.001) both only have a significant standard deviation but not a significant parameter coefficient. This means these two activities do not significantly influence travelers' choice between car and hub, while taste variations exist for these variables.

The adjusted R-squared shows a goodness of fit of 0.45, indicating a good fit.

5.3 Choice between transportation modes within the hub: model results

This section describes the results of travelers' transportation mode choices at the urban and regional hubs. People only chose a transportation mode when they chose to travel via the mobility hub.

5.3.1 Model results for transportation mode choice at the urban mobility hub

MNL model

Table 12 presents the results of the MNL regression analysis on mode choice at the urban multimodal mobility hub. The bus is the reference level for the estimations.

Table 12 Results MNL model for transportation mode choice at the urban hub

		Coefficients of basic MNL model - Transportation mode choice urban hub							
Variable	**Variable level**	**Alternative 1: Bus**	**St. Error**	**Alternative 2: Shared bike**	**St. Error**	**Alternative 3: Shared scooter**	**St. Error**	**Alternative 4: Shared car**	**St. Error**
Constant		0		-0.474	0.426	-3.107***	0.575	-0.81**	0.355
Travel time		0.01	0.07	0.00	0.045	0.04	0.047	0.05	0.084
Total price		-0.16	0.13	-0.02	0.055	0.08	0.081	0.03	0.051
Arrival frequency		0.02	0.06						
Gender	Male	0		-0.178**	0.073	-0.058	0.148	-0.065	0.098
	Female	0		0.178		0.058		0.065	
Age	18-34 years	0		0.173	0.170	0.956***	0.331	0.465**	0.213
	35-54 years	0		-0.262**	0.122	0.439*	0.264	-0.18	0.160
	55-64 years	0		0.199	0.144	-0.254	0.399	0.418**	0.174
	65 years and older	0		-0.11		-1.141		-0.703	
Income	Low	0		-0.007	0.178	-0.315	0.493	-0.17	0.231
	Middle	0		-0.125	0.119	0.254	0.328	-0.458***	0.149
	High	0		0.336	0.237	-0.65	0.794	0.669**	0.263
	No information	0		-0.204		0.711		-0.041	
Household	With children	0		0.166**	0.083	0.368**	0.169	-0.023	0.106
	Without children	0		-0.166		-0.368		0.023	
Familiarity with shared bike	Yes and use it	0		-0.207	0.192	0.478*	0.277	0.165	0.234
	Yes but do not use it	0		0.339***	0.120	0.004	0.203	0.225	0.150
	No	0		-0.132		-0.482		-0.39	
OV-card ownership	With subscription	0		-0.215**	0.107	-0.298	0.224	-0.613***	0.155
	Without subscription	0		-0.16	0.104	-0.103	0.209	0.356***	0.130
	No card	0		0.375		0.401		0.257	
Model fit	LL(0)	-1523.5							
	LL(β)	-1225.8							
	R^2	0.195							
	Adjusted R^2	0.189							

*Note. *p<.05, **p<.01, ***p<.001.*

The shared scooter (β=-3.11, p<.001) and shared car (β=-0.81, p<.01) have a significant negative parameter for the alternative specific constant, showing that individuals are less likely to choose these transportation modes. It also shows that the shared car is preferred over the shared scooter. The shared bike also has a negative parameter, albeit insignificant. The bus being preferred over the other transportation modes is in line with the percentage of the bus being chosen, which is 42.8%. The shared bike is chosen in 36.1% of the cases, the scooter in 5.5% of the choices, and the shared car is chosen in 15.6% of the cases. Travel time, total price of the trip, and the arrival frequency of the bus are all insignificant. The differences between the time and price of the transport modes are relatively small because of the shorter distances. People may not be sensitive to these (small) differences.

Furthermore, personal characteristics play a role in the preference for transportation modes. Looking at the results of the shared e-bike, men are less likely to choose this mode than women (β=-0.18, p<.01). Also, men are less likely to choose the shared bike compared to the other modes. Moreover, people between 35 and 64 years old (β=-0.26, p<.01) are less willing to choose the shared bike compared to other age groups, and travelers who own an OV-card subscription (β=-0.22, p<.01) are also less willing to choose the shared bike than people without a card or subscription. Unexpected is the result showing that people who are familiar with the shared bike but do not have experience using it, are more inclined to use the shared bike than other groups (β=0.34, p<.001). Perhaps they have never been in a situation where they could use the bike. Without extra information, this finding is however difficult to explain.

Looking at the shared scooter, younger people (18-34 years old) (β=0.96, p<.001) are more likely to choose this transport mode compared to other age groups and other transportation modes. People between 35 and 54 years old (β=0.44, p<.05) are also more inclined to use the shared scooter than

older people, and most likely to choose this mode compared to the other modes. Moreover, households with children (β=0.37, p<.01) prefer the scooter over the other modes and are more likely to choose the scooter than households without kids. This is unexpected as the scooter provides a way of transportation for only one person (maybe two), while a household often consists of more than one person. An explanation might be that people see the mobility hub as extra way of transportation besides the private car. For instance, one person in the household takes the car (with children) while the other person can travel via the hub taking the scooter (or another transportation mode).

Compared to other age groups, younger people (18-34 years old) (β=0.47, p<.001) are also more willing to use the shared car. More specifically, younger people prefer the shared e-scooter the most, after which the shared car, shared e-bike (although insignificant), and bus (reference level). Furthermore, people of 55 to 64 years old (β=0.42, p<.01) are also more inclined to choose the shared car compared to people of 35-54 years and 65 years and older. Additionally, income plays a role in the choice of shared car. Individuals with a middle income show a lower tendency to choose the shared car (β=-0.46, p<.001) while individuals with a high income are more likely to choose the shared car (β=0.67, p<.01) compared to the other groups.

Lastly, the adjusted R-squared is 0.19 which indicates a moderate model fit.

MNL model with interactions

Interaction effects are included to improve the model. Interactions between income and price, and age and price are included in the final model. Although the model performs slightly better ($R^2_{adjusted}$ = 0.20), only one interaction effect was significant, which was the interaction between people of 35-54 years old and price of the bus (β=-0.27, p<.05). This means that for people who are 35 to 54 years old, a higher bus price is associated with a significantly lower likelihood of choosing the bus. The results of this model are presented in Appendix D.

MXL model

A mixed logit random parameter model with panel effect is also estimated. The results can be found in Table 13. The variables *travel time* and *total price* are set as random for all transport modes. The alternative specific constant is also set as random for the shared bike, shared scooter, and shared car. All random variables are assumed to be normal as this gave the highest goodness of fit. This section only discusses the results of the random parameters and those parameters that became significant compared to the MNL model.

The standard deviation of the alternative specific constant of the shared bike (σ=1.07, p<.001), the shared scooter (σ=1.13, p<.001), and shared car (σ=1.20, p<.001) are all significant. This indicates variation in the sampled population concerning the preferences of these transportation modes. Moreover, preferences concerning travel time for the bus (σ=0.13, p<.001), shared bike (σ=0.04, p<.001), shared scooter (σ=0.03, p<.01), and shared car (σ=0.05, p<.001) are widely varied across people. Although travel time is not significantly affecting the utility functions of each mode, some people find travel time relevant for the choice while for others, the effect of travel time on the mode choice is more limited. Lastly, the results show that the standard deviation of the price of the shared bike (σ=0.06, p<.05) and shared car (σ=0.13, p<.001) is significant, referring to taste variations concerning these variables. The parameter coefficient of the total price of the shared bike also changed to being significant (β=-0.19, p<.001), which means that the willingness to choose the shared bike decreases when the price increases. Due to significant heterogeneity, price is more relevant for some people than others for the shared bike choice.

Applying the MXL model with panel effect also influenced the significance of several parameter coefficients. The results show that people between 18 to 34 years old are now more inclined to use the shared bike (β=0.76, p<.05), while people between 35 and 54 years old are less inclined to choose the shared car (β=-0.70, p<.01). The results also show that several personal characteristics are not significant anymore, most likely due to the application of the panel effect. The coefficients of the following groups for the shared bike are now insignificant: being a man, households with kids, familiarity with the shared bike, and ownership of OV-card subscription. For the shared scooter, it concerns a change in significance for people of 35-54 years old, households with kids, and familiarity with the shared bike and using it. The change in significance for groups of the shared car were people of 55-64 years old, low income, and OV-card ownership.

Table 13 Results MXL model for transportation mode choice at the urban hub

		Coefficients of basic MXL model - Transportation mode choice urban hub							
Variable	**Variable level**	**Alternative 1: Bus**	**St. Error**	**Alternative 2: Shared bike**	**St. Error**	**Alternative 3: Shared scooter**	**St. Error**	**Alternative 4: Shared car**	**St. Error**
Constant		0		-0.926	0.685	-4.05***	0.93	-1.66***	0.626
Travel time		0.08	0.10	0.07	0.06	0.05	0.07	-0.02	0.12
Total price		-0.42*	0.22	-0.191**	0.09	-0.12	0.11	0.00	0.08
Arrival frequency		0.10	0.09						
Gender	Male	0		-0.147	0.161	-0.117	0.243	-0.267	0.204
	Female	0		0.147		0.117		0.267	
Age	18-34 years	0		0.764*	0.395	2.020***	0.628	1.631***	0.49
	35-54 years	0		-0.625**	0.261	0.526	0.46	-0.695**	0.34
	55-64 years	0		0.082	0.317	-0.994	0.662	0.220	0.361
	65 years and older	0		-0.221		-0.500		-1.156	
Income	Low	0		0.310	0.374	-0.126	0.690	-0.435	0.430
	Middle	0		0.042	0.269	0.461	0.487	-0.512*	0.289
	High	0		-0.398	0.576	-1.472	1.183	0.517	0.532
	No information	0		0.046		1.136		0.430	
Household	With kids	0		0.284	0.181	0.295	0.274	0.010	0.218
	Without kids	0		-0.284		-0.295		-0.010	
Familiarity with shared bike	Yes and use it	0		-0.533	0.428	0.341	0.559	-0.437	0.462
	Yes but do not use it	0		0.279	0.282	-0.338	0.393	0.430	0.292
	No	0		0.255		-0.003		0.007	
OV-card ownership	With subscription	0		-0.110	0.237	-0.138	0.376	-0.834***	0.293
	Without subscription	0		-0.286	0.225	0.004	0.349	0.336	0.258
	No card	0		0.396		0.134		0.498	
Random variable	sd. Constant			1.074***	0.213	1.127***	0.393	1.302***	0.304
	sd. Travel time	0.129***	0.020	0.043***	0.012	0.030**	0.014	0.049***	0.018
	sd. Total price	0.018	0.059	0.061*	0.037	0.035	0.04	0.131***	0.038
Model fit	LL(0)	-1523.5							
	LL(β)	-1073.1							
	R^2	0.296							
	Adjusted R^2	0.290							

*Note. *p<.05, **p<.01, ***p<.001.*

5.3.2 Model results for transportation mode choice at the regional mobility hub

MNL model

Table 14 shows that the alternative specific constant is significantly negative for the shared bike (β=-1.1, p<.001), shared scooter (β=-2.04, p<.001), and shared car (β=-0.56, p<.05). This means that the train (reference level) is most likely to be chosen, after which the shared car, shared bike, and shared scooter (in that order).

Table 14 Results MNL model for transportation mode choice at the regional hub

		Coefficients of basic MNL model - Transportation mode choice regional hub							
Variable	**Variable level**	**Alternative 1: Train**	**St. Error**	**Alternative 2: Shared bike**	**St. Error**	**Alternative 3: Shared scooter**	**St. Error**	**Alternative 4: Shared car**	**St. Error**
Constant		0		-1.1***	0.278	-2.04***	0.454	-0.556*	0.322
Travel time		-0.528***	0.16	-0.111***	0.03	-0.109***	0.035	-0.344***	0.11
Total price		-0.037	0.0547	0	0.03	-0.041	0.052	-0.095***	0.03
Arrival frequency		0.065	0.08						
Gender	Male	0		0.189	0.116	0.192	0.185	-0.078	0.115
	Female	0		0.189		-0.192		0.078	
Age	18-34 years	0		-0.406*	0.244	-0.484	0.377	-0.546*	0.285
	35-54 years	0		-0.182	0.164	-0.175	0.250	-0.186	0.166
	55-64 years	0		0.490***	0.184	-0.41	0.364	0.135	0.196
	65 years and older	0		0.098		1.069		0.597	
Income	Low	0		0.401	0.266	1.667***	0.478	0.213	0.293
	Middle	0		-0.074	0.171	0.523	0.372	0.171	0.179
	High	0		-0.24	0.293	-1.657*	0.850	-0.498	0.346
	No information	0		-0.087		-0.533		0.114	
Household	With children	0		0.319***	0.113	0.554***	0.175	0.195*	0.116
	Without children	0		-0.319		-0.554		-0.195	
Familiarity with shared bike	Yes and use it	0		0.986***	0.211	1.602***	0.296	-0.091	0.32
	Yes but do not use it	0		-0.831***	0.156	-1.155***	0.243	-0.183	0.19
	No	0		-0.155		-0.447		0.274	
OV-card ownership	With subscription	0		-0.457***	0.162	-0.474	0.259	-0.891***	0.179
	Without subscription	0		0.091	0.153	0.017	0.238	0.184	0.149
	No card	0		0.366		0.457		0.707	
Model fit	LL(0)	-1110.4							
	LL(β)	-777.7							
	R^2	0.300							
	Adjusted R^2	0.292							

*Note. *p<.05, **p<.01, ***p<.001.*

As expected, the travel time is significantly negative for the utility functions of the train (β=-0.53, p<.001), shared bike (β=-0.11, p<.001), shared scooter (β=-0.11, p<.001), and shared car (β=-0.34, p<.001). It means that individuals, as expected, do prefer a shorter travel time. The negative influence of the travel time contributes most to the utility function of the train, after which the shared car, bike, and scooter. As travel time did not significantly affect the utility functions of the modes within the urban hub, these results show that travel time becomes more important when the distance becomes larger. Moreover, the total price for the shared car has a negative parameter estimate (β=-0.1, p<.001), indicating that the higher the price, the lower the likelihood of choosing the shared car. The reason for other cost parameters not insignificant can be associated with the relatively low price of those alternatives. Different price levels do not make much difference in this case.

Looking at personal characteristics, the results show a high tendency to choose the shared bike among individuals between 55 and 64 years old (β=0.49, p<.001), while this tendency is low for young people between 18-34 years old (β=-0.41, p<.05). Also, individuals who are part of a household with children (β=0.32, p<.001) are more likely to choose the shared bike compared to households without children. The highest significant and positive parameter is for the group of people who are familiar with and use the shared bike (β=0.99, p<.001), while those individuals who are familiar but do not use the shared bike have a low tendency to use this transport mode (β=-0.83, p<.001). Having an OV-card subscription also reduces the probability of choosing the shared bike (β=-0.46, p<.01). As this group already pays for public transport via their subscription, it is expected that they are most likely to use public transport (i.e., the train).

For the shared scooter, the results show that individuals with a low income have a high interest in this mode (β=1.67, p<.001). Also, individuals from households with children have a higher tendency to

choose the shared scooter compared to the train and bike (β=0.55, p<.01). This preference was also the case for transportation mode choice at the urban hub. Familiarity with the shared bike plays a role as well. This group has a significant and positive parameter for the choice of shared scooter (β=1.60, p<.001). However, the group that is familiar but does not use the shared bike is less interested in the shared scooter (β=-1.16, p<.001) compared to the other offered transportation modes.

For the shared car, three individual characteristics are significant. People who are 18 to 34 years old are less inclined to use the shared car compared to the other transport modes (β=-0.55, p<.05), and compared to other age groups. Also, households with children are more inclined to use the shared car (β=0.20, p<.05) than those who do not have children. Specifically, households with children prefer the shared scooter most, after which the shared bike, shared car, and train. Finally, the ownership of an OV-card with subscription reduces the probability of choosing the shared car (β=-0.89, p<.001). For this last group, the parameter coefficients for all shared modes are negative. As this group already pays for public transport, this result is expected.

Lastly, the adjusted McFadden R-squared shows a good model fit of 0.29 ($R^2_{adjusted}$=.29).

MNL model with interactions

Two-way interaction effects are added to improve the performance of the model. Multiple interaction effects were tested and the final model eventually included the following two-way interactions: Income with total price, and age with total price. Other interaction effects that were tested are gender with time and price, age with time, and households with kids with time. The final model had the highest goodness of fit ($R^2_{adjusted}$=.31), although none of the interaction effects were significant. The model is included in Appendix D.

MXL model

The last estimated model is the random parameter mixed logit model with panel effect for the transportation mode choice at the regional hub. The results are presented in Table 15.

The standard deviation of the alternative specific constant of the shared scooter (σ=2.16, p<.001) and shared car (σ=1.36, p<.001) are significant. This refers to heterogeneity concerning the preference of these transport modes. The standard deviations of travel time of the shared bike (σ=0.05, p<.001), the shared scooter (σ=0.14, p<.001), and shared car (σ=0.24, p<.001) are also significant, indicating that people value the importance of travel time differently for these modes. The same accounts for the standard deviation of the costs which is significant for the train (σ=0.56, p<.001), shared bike (σ=0.06, p<.01), shared scooter (σ=0.24, p<.001), and shared car (σ=0.12, p<.001). It thus indicates there are different individual-specific parameter estimates for each individual, which deviates from the mean of the parameter estimate.

Furthermore, the price coefficient of the shared scooter became significantly negative (β=-0.29, p<.01). This refers to a decrease in willingness to choose the shared car when the price increases, which is as expected. The coefficients of the alternative specific constant of the shared bike and shared scooter are now insignificant. Also, the coefficients for people of 18-34 years old (shared bike and shared car), with a middle income (shared scooter), being familiar with the shared bike (shared bike and shared scooter) are now insignificant.

McFadden adjusted McFadden R-squared shows a good model fit ($R^2_{adjusted}$=.462).

Table 15 Results MXL model for transportation mode choice at the regional hub

		Coefficients of basic MXL model - Transportation mode choice regional hub							
Variable	**Variable level**	**Alternative 1: Train**	**St. Error**	**Alternative 2: Shared bike**	**St. Error**	**Alternative 3: Shared scooter**	**St. Error**	**Alternative 4: Shared car**	**St. Error**
Constant		0		-0.233	0.582	-1.304	1.017	1.68**	0.843
Travel time		-1.1***	0.35	-0.25***	0.07	-0.336***	0.08	-0.719***	0.252
Total price		0.09	0.14	-0.05	0.07	-0.292**	0.14	-0.32***	0.075
Arrival frequency		-0.06	0.15						
Gender	Male	0		-0.078	0.261	0.574	0.478	0.2798	0.352
	Female	0		0.078		-0.574		-0.2798	
Age	18-34 years	0		-0.176	0.568	0.476	1.008	-0.451	0.819
	35-54 years	0		-0.618	0.391	-0.616	0.655	-0.717	0.561
	55-64 years	0		0.940*	0.491	-0.825	0.979	0.466	0.582
	65 years and older	0		-0.146		0.965		0.702	
Income	Low	0		0.913	0.592	2.738**	1.175	0.853	0.781
	Middle	0		-0.591	0.417	-0.187	0.88	-0.909	0.600
	High	0		-0.011	0.663	-3.529	2.15	-0.323	0.929
	No information	0		-0.311		0.978		0.379	
Household	With kids	0		0.506*	0.283	-0.38	0.47	0.729*	0.406
	Without kids	0		-0.506		0.38		-0.729	
Familiarity with shared bike	Yes and use it	0		0.887	0.561	1.503*	0.908	-0.171	0.794
	Yes but do not use it	0		-0.951***	0.369	-0.890	0.652	-0.092	0.497
	No	0		0.064		-0.613		0.264	
OV-card ownership	With subscription	0		-0.799**	0.393	-1.140	0.710	-1.814***	0.550
	Without subscription	0		0.121	0.345	-0.214	0.694	0.445	0.447
	No card	0		0.678		1.354		1.369	
Random variable	sd. Constant			0.062	0.413	2.157***	0.639	1.362***	0.528
	sd. Travel time	0.009	0.032	0.047***	0.011	0.142***	0.023	0.239***	0.065
	sd. Total price	0.559***	0.08	0.056**	0.026	0.249***	0.055	0.123***	0.035
Model fit	LL(0)	-1110.4							
	LL(β)	-596.6							
	R^2	0.463							
	Adjusted R^2	0.458							

*Note. *p<.05, **p<.01, ***p<.001.*

6 Discussion

This research aims to answer three research questions on the topic of the multimodal mobility hub. By collecting stated choice data and performing an MNL and MXL analysis, efforts are made to answer the questions. In this chapter, the results of these analyses will be interpreted and discussed for each research question separately (section 6.1). Besides, limitations (section 6.2), recommendations for future research (section 6.3), and practical implications (section 6.4) are discussed in this chapter.

6.1 Main findings and theoretical implications

6.1.1 Mobility hub use, private car substitution

The first research question is defined as *"To what extent is the multimodal mobility hub in urban and regional areas able to substitute car use?"*. Based on the collected data, it seems there is still a clear preference for the private car. The results show that car drivers choose to substitute their car for the urban mobility hub in 30.5% of the choice situations and for the regional hub in 21.2% of the choice situations. This suggests that the hub has limitations in fully substituting car use. The low share of substitution can be partly attributed to the target group of this research. Van der Meer (2022) investigated potential user groups of the mobility hub by conducting a latent class cluster analysis and found that car drivers have the lowest intention to use the hub. This implies that the potential use of the multimodal mobility hub is likely to be higher than this research suggests. Several factors were identified that influenced the choice between the private car and the hub, indicating that there is some potential for substitution of the private car.

Weather conditions is one of the factors, with individuals being more likely to travel via the hub when it is sunny. This is the case for both the urban and regional hub. It implies that favorable weather may encourage people to use alternative ways of transportation, while bad weather tends to steer people towards using their cars. This is in line with research from Hyland et al. (2018), who pointed out the increasing reliance on private cars in case of windy and rainy weather.

Moreover, while the primary trip purpose does not affect individuals' choices, secondary trip purposes can influence this. Attending a business meeting or shopping for groceries can increase the willingness to travel via the hub. While the influence of attending a business meeting on the decision to use the hub applies to both the urban and regional hub, shopping for groceries only influences the willingness to travel via the regional hub. Traveling via the regional hub usually incorporates larger travel distances (and longer travel time), making people seemingly more willing to combine multiple activities. The preferences regarding conducting activities at the hub vary. This means that for some people, doing such activities at the hub is more important than for others.

Furthermore, the distance between origin and destination influences the willingness to travel via the hub. The likeliness of an individual traveling via the urban or regional hub increases as the travel distances decrease, and at the same time, increasing travel distance further increases the choice for the private car. This could explain the higher percentage of people choosing the urban hub compared to the regional hub, as the latter incorporates larger travel distances. Thus, the findings generally suggest that the hub may be more appealing for shorter trips.

As expected, parking price appeared to be another influential factor. Parking costs at the destination for the private car influence the choice in both the urban and regional setting: the higher the parking price at the destination for the private car, the more likely individuals are to travel via the hub. Parking costs at the hub are only relevant for the urban hub; when parking is free of charge, individuals are more likely to choose this type of hub for their journey. A reason that the price is only important for the urban hub is that the other costs (i.e., fuel costs, rental costs for shared bike, etc.) are generally

lower in this situation. Therefore, the parking costs in the urban situation impact the total price relatively more than (they do) in the regional situation. It implies that people are price sensitive to a certain extent and opt for relatively low costs.

Transfer time only affects individuals' preferences regarding the regional hub. Travelers prefer a larger transfer time at this type of hub over a short transfer time. This contradicts the research of Claasen (2020), which showed that transfer time should be minimized. Claasen's research, however, focuses on neighborhood hubs near city centers. In the situation of regional hubs, larger distances have to be traveled by individuals. Therefore, this might imply that travelers prefer to transfer at a larger hub when they have to travel for a longer time.

The extent to which the hub can substitute the private car is also dependent on the personal characteristics of individuals. Several groups are more or less inclined than average to substitute their private car and travel via the mobility hub.

People between 55 and 64 years old are less willing to travel via both the urban and regional mobility hubs. This is as expected and in line with previous findings (Claasen, 2020; Prieto et al., 2017). The level of education and income plays a role as well. In line with previous research (e.g., Bösehans et al., 2023; Claasen, 2020), people with higher education and income are more likely to use the hub than those with lower income and education. People with lower income and education are often categorized as late majority or laggards following Roger's diffusion of innovation theory (1995) (Burghard & Dütschke, 2019). This means that they adopt a new concept when it has been normalized. Low income, low education, and middle education influence the willingness to use the urban hub. Middle income affects the inclination to use the regional hub.

People owning an OV-card with a subscription are more inclined to use the urban and regional mobility hub. This is as expected, as owning an OV-card with subscription indicates familiarity with collective transport modes and sharing transportation modes with others. Given that public transport is also accessible at the hub, it is not surprising that individuals with an OV-card subscription are more likely to travel via the hub than those without such a subscription. Public transport users were also identified as early adopters of new transport alternatives (Claasen, 2020; van der Meer, 2022). Additionally, those familiar with the shared bike but not using it tend to prefer their private car. This can be attributed to their prior decision not to use shared mobility. As the mobility hub is also a new and more sustainable way of transportation that offers three types of shared mobility, it seems reasonable that this group is also less willing to use the hub.

Furthermore, the ownership of one car increases the probability of traveling via the urban hub, possibly because the car is not always available (if used by other household members). Owning two cars, however, decreases the probability of traveling via the regional hub. In contrast to owning one car, there is no need for an extra transport mode.

People driving a car 1-2 times per week are more inclined to use the urban hub than average. Similarities can be found in the research of Bösehans et al. (2023) about user groups of e-mobility hubs. They call this group 'flexible car-lovers', referring to people who "rely on the convenience of the private car, yet are open to other transport alternatives" (p. 209), and categorize this group as the highest potential users. Although this is not specifically the case in this research, the results imply that this group should be considered as potential users. Besides this, the (urban) mobility hub provides an opportunity for those who regularly rely on being passengers in cars as it provides alternatives that do not require dependency on others (i.e., the driver of the car).

In conclusion, the findings of the study show that both the urban and regional hub can substitute the private car to a limited extent. However, the urban hub is more likely to substitute the private car than the regional hub. This difference is most likely due to shorter distances that are covered when traveling via the urban hub. Nonetheless, the preference for the private car remains significantly higher for both types of hubs.

Particular situations can lead to an increased probability of choosing the hub over the private car. For both hubs, this is in case of sunny weather, having a business meeting, high parking fees for the private car at the destination, and relatively short travel distances. The urban hub can become more attractive as well when parking is free of charge at the hub. The regional hub can benefit if transfer times are larger and people can do their groceries at the hub.

6.1.2 Contribution of facilities and services

The second research question is *"Does the existence of facilities and services contribute to willingness to use a multimodal mobility hub?"*.

Offering facilities and services has a limited effect on the willingness to use the urban multimodal mobility hub. Of the seven potentially offered facilities, only one seemed to influence the choice of individuals to travel via this type of hub. This is the social extended reality office space. This is in line with people willing to travel via the hub for a business meeting. One reason for the lack of interest in the other facilities at the urban hub could be the proximity of these facilities already in the area.

The contribution of facilities and services to the willingness to use the regional mobility hub is higher. The intention to use the hub increases with the availability of a supermarket, café, or social extended reality office space, while the other facilities do not create a difference. This is different when heterogeneity among various variables is assumed. When that is the case, the availability of a gym also contributes to the willingness to use the hub. The availability of a drug store and medicine pick-up point, however, reduces the likelihood of choosing the hub. This is unexpected because individuals are not obliged to use a facility. To explain this finding, further investigation is required.

A clear difference is visible between the urban and regional hubs regarding facilities' contribution to the willingness to use the hub. It shows that when people have longer travel times, they like to have more facilities. This seems reasonable as it is, for example, nice to have a cup of coffee on your way when traveling for a longer time.

The first research question showed that people generally prefer a larger regional mobility hub (i.e., larger transfer time) and are more willing to travel via the hub when they have to/can do additional activities (i.e., business meeting and grocery shopping). Connecting this to the second research question shows that when individuals travel larger distances, the hub becomes more attractive when it facilitates multiple activities at the location.

6.1.3 Transportation mode choice at the urban and regional hub

The third research question is *"What is the likelihood of each individual transportation mode to be chosen by those willing to use the hub and which factors influence this choice?"*

Urban mobility hub

For the urban mobility hub, four transportation modes could be chosen: the bus, shared e-bike, shared e-scooter, and shared car. People are most likely to choose the bus (reference level), after which the shared e-bike (insignificant), the shared car, and shared scooter. There is, however, considerable variation between individuals concerning their preferences for transport modes. Travel time and arrival frequency did not affect the choice of one of the transport modes. The limited effect of travel

time can be attributed to the relatively small differences between the values in the context of the urban hub (i.e., relatively short distances). However, there is heterogeneity concerning the importance of travel time; some people are more sensitive to travel time changes than others. Trip price affects the willingness to choose the bus and shared bike. A higher price decreases the willingness to use each mode. Price does not seem to be important for individuals' willingness to use the shared car or scooter. People might be less price sensitive for these modes when short distances are traveled.

Moreover, several personal characteristics play a role in mode choice. Young adults prefer shared modes (in the order of shared scooter, car, and bike) over the bus. This is expected as multiple studies show that shared mobility users are usually younger people (e.g., (Burghard & Dütschke, 2019; Narayanan & Antoniou, 2023; van der Meer, 2022). The flexibility and autonomy the shared modes provide could be a reason for this; autonomy is an important determining factor when choosing between transport modes (Simons et al., 2014), and it is often a reason why people use a car (Hunecke et al., 2021). Furthermore, middle-aged people (35-54 years old) are less inclined to choose a shared car and bike than a shared scooter and bus, and people owning OV-card subscriptions are less likely to travel by shared car from the hub. It seems reasonable that these people are not paying for another car when they already pay fixed charges for their private car and pay for public transport services.

Regional mobility hub

The regional hub also offers four transportation modes: the train, shared e-bike, shared e-scooter, and shared car. Although there is considerable variation concerning transport mode preferences, the shared car is most likely to be chosen as transport mode, after which the train (reference level), shared bike, and shared scooter (although shared scooter and bike were insignificant). The shared bike and scooter have negative signs, which might imply that slower modes are less preferred for longer distances. This would complement other studies that point out that the probability of people using shared micro-mobility for distances larger than 5 km is relatively small (Claasen, 2020; Narayanan & Antoniou, 2023).

Furthermore, travel time affects the willingness to use all transport modes. The likeliness of choosing each transportation mode decreases as the mode's travel time increases. This effect is the strongest for the choice for the train. This is unexpected as the train provides the opportunity for travel-based multitasking. It was therefore expected that the negative effect of increasing travel time would be less for this mode than for others. The trip price is another determining factor in the decision-making between the transportation modes. Higher costs for the shared scooter and car decrease the willingness to use these modes. A reason that price does not affect the choice for the train and shared bike is that the costs for these modes are already lower than those for the shared scooter and car. There is also significant heterogeneity; different individuals are willing to pay different amounts for the same transport mode. A reason could be that some people find sustainable transport more important than others and are therefore willing to pay more, which is also explained by Doran et al. (2015).

Looking at personal characteristics, households with children are more likely to choose the shared car, after which the shared bike. While the first is as expected because it provides space to travel with multiple people, this is not the case for the shared bike. Of course, individuals in households with children do not always have to travel with children. Thus, the shared bike might serve as an extra transportation mode when traveling alone. Familiarity with the shared bike also affects the transportation mode choice. Previous findings showed that prior experience with shared mobility increases the likelihood of using it again (Horjus et al., 2022). This study shows a higher likelihood of

using the shared scooter by shared bike users. An explanation that the shared scooter is preferred over the shared bike could be that the scooter is more comfortable for larger distances. Moreover, individuals who own an OV-card subscription derive negative utility from all shared modes compared to the train. This aligns with the findings obtained from the urban hub. The implementation of MaaS could be a solution to attract OV-card owners to shared mobility modes. Shared services and public transport are offered and paid for on the same platform (Feneri et al., 2020; Jittrapirom et al., 2017). Finally, individuals with a low income are more likely to choose the shared scooter than average. This would be counterintuitive as low-income households are generally less likely to choose shared modes (Claasen, 2020). However, the choice situation only included shared modes and the train, and no private vehicle. More research would be necessary to find out any motivations.

6.2 Limitations

This research encountered several limitations, which are briefly discussed in this section.

One limitation concerns the methodology used in this research. Limitations of the stated choice experiment are already discussed in section 3.2 (i.e., the issue of realism, hypothetical scenarios, and no direct behavioral change). However, one of these limitations should be elaborated a bit more. As mentioned, the experiment consisted of hypothetical scenarios and in this research, it was assumed that the status quo involved each trip being made by private car. However, in practice, this is not always the case. Although the target group of this research was frequent car drivers, it does not mean that all trips, especially the shorter trips, are made by car. This limitation could have been solved by adding a 'no-choice' option or using a stated adaption experiment in which the respondents had to report their own trips made by car and answer the questions based on these trips. However, it is chosen to conduct a stated choice experiment, limiting the complexity of the survey and the burden on respondents. This affects the realism of the experiment and should therefore be pointed out as a limitation.

In addition, the multimodal mobility hub is not yet a widely implemented and used concept. This results in people being unfamiliar with the concept. As mentioned, this was the reason for using the stated choice experiment, as it provides the opportunity to measure preferences concerning new non-existing alternatives. However, it also comes with the limitation that attitudes toward the hub might change once people become more familiar with the concept, considering that this choice is only hypothetical and not a real-life choice (Train, 2003). By explaining the concept of the hub and showing a video, effort was made to reduce the impact of unfamiliarity.

Another important aspect to be discussed is the generalizability of this research. The sample consists of older people with a higher income and education compared to the Dutch population. Most importantly, this research only included frequent car drivers and, thus, can only forecast the demand for this target group to a certain extent. It is expected that the mobility hub's demand will be higher than this research presents as the hub provides an easy opportunity for traveling for people who do not own a car or do not want to be dependent on the use of a car. Moreover, Dutch infrastructure is different from other countries as well as the temperate weather. Therefore, it is likely that different choices are made in other countries.

Finally, the motives or barriers behind certain choices are unknown. No "why-question" is asked, making it difficult to explain why certain choices are made (or not made). Focus groups or interviews could help identify other underlying motives or barriers.

6.3 Future research

Based on this study, several recommendations for future research are provided. Although only a limited number of suggestions will be proposed, it should be mentioned that the collected data offer many opportunities for further analyses that can be relevant for both researchers and policy makers. Only the most relevant recommendations based on this research are pointed out.

First of all, conducting analyses on the simultaneous choice of hub and transport modes is recommended. Currently, it is assumed that respondents first choose whether they travel by private car or via the hub, after which they choose which transportation mode they will use once they choose to travel via the hub. However, travelers will often make a simultaneous choice between five choice alternatives; traveling by private car, shared bike, shared scooter, shared car, or bus/train.

Moreover, the results of this research showed the importance of price. For example, we saw that free parking at the hub is preferred and a higher price for parking for the private car is undesired. Interesting would be to estimate the willingness to pay for the mobility hubs. Are people willing to pay more for the hub, and if so, to what extent? A total trip price per alternative (including parking, fuel, and rental prices) should be estimated for this.

As mentioned, the collected data offer many opportunities for further analyses. For example, data about attitudes concerning multimodality and environmental friendliness are collected but are not used in this study. A hybrid choice model can include these attitudinal variables to investigate whether these attitudes impact hub and transport mode choice. Data are also collected on the mode choice with which travelers would arrive at the hub. Analyzing these data can create a complete picture of travelers' trips via the hub.

Finally, the literature review elaborated on the close connection between the multimodal mobility hub and MaaS (section 2.3). It is advised to investigate to what extent MaaS can contribute to car substitution by traveling via the hub. As MaaS can simplify the decision-making for the trip compared to how it is presented in this study, it might also increase the demand for the hub.

6.4 Practical implications

This research concludes with three practical implications for municipalities, policymakers, transport planners, or even researchers.

First of all, considering the influence of travel distance on the willingness to use the hub and substitute one's car, the location of the mobility hub seems to be an important issue. As especially the distance to be covered seems to be a limitation for individuals when the distance becomes longer, it is advised to locate the hub on strategic locations relatively near points of interest (i.e., business centers, city centers).

Furthermore, the results of this study can be used as a guideline for designing a multimodal mobility hub. It presents several facilities and services that can increase the adoption of the hub. It also offers information about the transportation modes that can be available. In addition, it can be used in what not to include at the hub. In such a way, an evidence-based design of the multimodal mobility hub can be developed.

Specifically, when a hub has a regional function, the demand for a larger hub with more facilities becomes higher. For instance, people want to be able to attend a business meeting, to do their groceries, or grab a cup of coffee. Based on the location, it is advised to offer a variety of services at the hub.

Preferences regarding transportation modes vary, but especially for larger distances, travel time is important. Reducing travel time would most likely increase the use of transport modes at the hub. Although this might be difficult to accomplish, fast lanes can, for example, be constructed from the hub to business centers (or other locations).

In addition, it shows the importance of cost incentives. For the hub to be as accessible as possible, parking price is advised to keep free of charge (or as low as possible), while asking for high(er) parking fees for the private car. A multifold of policies should be implemented to reduce car use and let people switch to alternative modes of transport.

By considering this research with practical implications, strategies can be developed to maximize the effectiveness and adoption of the multimodal mobility hub, contributing to a more sustainable and efficient mobility system.

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Appendix A. Average speed

Average speed in urban area	<4km	4-8 km	8-12 km	>=12 km
Bus	18 km/h	25 km/h	30 km/h	35 km/h
Shared e-bike	20 km/h	21 km/h	22 km/h	23 km/h
Shared e-scooter	20 km/h	21 km/h	22 km/h	23 km/h
Shared car	20 km/h	30 km/h	35 km/h	40 km/h

Average speed in regional area	<10 km	10-15km	15-20km	>=20km
Train	110 km/h	110 km/h	110 km/h	110 km/h
Shared e-bike	23 km/h	23 km/h	23 km/h	23 km/h
Shared e-scooter	23 km/h	23 km/h	23 km/h	23 km/h
Shared car	70 km/h	75 km/h	80 km/h	85 km/h

Appendix B. SAS output

Design SAS

```
Saturated      = 53
Full Factorial = 34,359,738,368
Some Reasonable                    Cannot Be
   Design Sizes       Violations    Divided By
            64 *                0
           128 *                0
            96                  1    64
            80                 19    32 64
           112                 19    32 64
            56                 77    16 32 64
            72                 77    16 32 64
            88                 77    16 32 64
           104                 77    16 32 64
           120                 77    16 32 64
            53 S              253     2  4  8 16 32 64
* - 100% Efficient design can be made with the MktEx macro.
S - Saturated Design - The smallest design that can be made.
    Note that the saturated design is not one of the
    recommended designs for this problem.  It is shown
    to provide some context for the recommended sizes.
```

Design SAS

Algorithm Search History

```
                          Current          Best
Design    Row,Col  D-Efficiency  D-Efficiency  Notes
-----------------------------------------------------------
     1      Start      100.0000      100.0000  Tab
     1        End      100.0000
```

Design SAS

```
   The OPTEX Procedure
  Class Level Information
Class  Levels  Values
x1        2    1 2
x2        2    1 2
x3        2    1 2
x4        2    1 2
x5        2    1 2
x6        2    1 2
x7        2    1 2
x8        2    1 2
x9        2    1 2
x10       2    1 2
x11       2    1 2
x12       4    1 2 3 4
x13       4    1 2 3 4
x14       4    1 2 3 4
x15       4    1 2 3 4
x16       4    1 2 3 4
x17       4    1 2 3 4
x18       4    1 2 3 4
x19       4    1 2 3 4
x20       4    1 2 3 4
x21       8    1 2 3 4 5 6 7 8
x22       8    1 2 3 4 5 6 7 8
```

Design SAS

Design Number	D-Efficiency	A-Efficiency	G-Efficiency	Average Prediction Standard Error
1	100.0000	100.0000	100.0000	0.9100

Design SAS
Canonical Correlations Between the Factors
There are 0 Canonical Correlations Greater Than 0.316

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22
x1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
x10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
x11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
x12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
x13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
x14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
x15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
x16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
x17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
x18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
x19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
x20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
x21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
x22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

SAS block design

Design SAS

Obs	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	Block
1	1	2	2	1	2	2	2	1	2	2	2	3	1	3	2	4	1	1	1	1	4	5
2	2	2	1	1	1	1	2	1	2	2	1	3	2	3	4	3	1	2	2	4	7	7
3	2	1	1	2	1	2	1	1	2	2	1	1	3	4	2	4	2	2	4	3	7	4
4	2	2	1	1	2	2	2	2	2	1	2	4	2	4	2	1	4	1	2	1	2	4
5	1	1	1	1	1	1	2	2	1	2	2	2	2	4	2	2	2	4	2	3	4	8
6	2	1	2	1	2	1	1	1	1	1	1	4	2	1	1	2	3	2	3	4	4	4
7	1	2	1	2	2	1	1	1	1	1	1	3	3	4	2	3	4	3	4	1	1	8
8	1	2	1	2	2	1	1	1	2	2	1	2	2	4	3	4	3	1	1	4	8	3
9	2	2	1	1	2	1	1	1	1	1	2	3	4	1	2	1	2	2	1	2	8	1
10	1	2	2	1	1	1	2	2	1	2	1	1	4	4	1	1	3	4	4	1	8	7
11	1	1	2	2	1	2	1	2	1	2	1	3	1	3	3	2	4	4	2	2	8	4
12	2	2	2	2	2	2	2	1	2	2	1	3	2	2	2	2	3	4	4	2	3	6
13	1	2	2	1	1	2	1	1	1	1	1	3	3	1	4	2	2	1	2	3	6	3
14	1	1	1	1	2	2	2	1	1	1	1	1	2	3	4	4	3	3	2	2	1	1
15	2	2	1	1	2	1	1	1	2	2	2	2	1	1	3	2	1	4	4	3	1	2
16	2	2	1	1	1	2	1	2	1	2	1	4	4	2	4	3	3	1	1	3	3	8
17	2	2	2	2	1	2	1	1	1	1	2	3	4	4	4	4	4	4	3	4	2	2
18	1	1	2	2	1	1	2	1	2	2	1	4	3	2	3	2	2	3	1	1	2	1
19	2	1	2	1	2	1	1	1	2	2	1	1	3	1	4	1	4	4	2	1	3	5
20	1	1	1	1	1	2	1	1	1	1	2	4	1	1	3	1	3	1	4	1	7	6
21	2	1	2	1	1	1	2	1	2	2	2	4	4	3	3	4	4	2	4	2	6	8
22	1	1	2	2	1	2	1	2	2	1	1	2	4	3	2	1	3	2	3	3	1	5
23	1	1	2	2	2	1	1	1	1	1	2	4	1	4	1	4	1	3	2	3	3	7
24	1	1	2	2	1	1	2	1	1	1	1	1	2	2	2	1	1	1	4	4	6	2
25	1	2	1	2	1	1	2	1	1	1	2	2	4	2	1	2	4	1	2	2	7	5
26	2	2	2	2	2	1	1	2	2	1	1	1	1	3	3	1	2	1	2	4	5	8
27	1	1	1	1	2	1	1	2	1	2	1	3	1	2	1	3	2	2	4	4	2	5
28	2	1	1	2	2	2	2	1	2	2	2	4	4	2	1	1	2	4	2	4	1	3

Obs	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	Block
29	1	1	2	2	2	2	2	2	2	1	2	3	3	1	1	4	3	4	1	4	7	8
30	2	1	2	1	2	2	2	2	1	2	1	2	1	4	4	1	2	3	1	2	7	2
31	1	2	2	1	1	2	1	1	2	2	1	2	2	1	1	1	1	3	3	2	2	8
32	1	2	2	1	2	2	2	1	1	1	2	2	4	3	3	3	2	3	4	4	3	4
33	1	2	2	1	2	1	1	2	1	2	2	4	3	2	2	4	3	2	2	2	5	2
34	2	1	1	2	2	1	1	2	1	2	2	3	2	3	1	1	4	3	1	3	6	6
35	2	1	2	1	1	2	1	2	1	2	2	3	2	2	3	4	2	1	3	1	1	7
36	2	2	2	2	1	2	1	1	2	2	2	2	1	4	1	3	3	2	2	1	6	1
37	1	2	1	2	1	2	1	2	2	1	2	1	2	3	1	2	2	2	1	1	3	2
38	2	1	1	2	2	1	1	2	2	1	2	2	3	3	4	2	3	1	4	2	2	7
39	2	1	2	1	1	1	2	1	1	1	2	1	1	3	2	3	3	4	1	3	2	3
40	1	2	1	2	2	2	2	2	1	2	1	1	4	1	3	4	1	2	2	3	2	6
41	2	2	1	1	1	2	1	2	2	1	1	1	1	2	1	4	4	3	4	2	4	3
42	2	1	2	1	1	2	1	2	2	1	2	2	3	2	2	3	1	3	2	4	8	6
43	2	2	1	1	1	1	2	1	1	1	1	2	3	3	1	4	2	4	3	1	5	6
44	1	2	1	2	1	1	2	1	2	2	2	3	1	2	4	1	3	3	3	3	5	4
45	1	1	2	2	2	2	2	2	1	2	2	2	2	1	4	3	4	2	4	1	5	3
46	1	1	1	1	2	1	1	2	2	1	1	2	4	2	4	4	1	4	1	1	6	4
47	2	1	1	2	2	2	2	1	1	1	2	1	1	2	4	2	1	2	3	1	8	8
48	1	2	2	1	1	1	2	2	2	1	1	4	1	4	4	2	4	2	1	4	1	6
49	2	1	2	1	2	2	2	2	2	1	1	3	4	4	1	2	1	1	4	3	5	1
50	2	2	2	2	1	1	2	2	2	1	2	4	2	1	4	4	2	3	4	3	8	5
51	2	2	2	2	1	1	2	2	1	2	2	1	3	1	1	3	1	1	1	2	1	4
52	1	2	2	1	2	1	1	2	2	1	2	1	2	2	3	3	4	4	3	3	7	1
53	1	1	1	1	1	2	1	1	2	2	2	1	4	1	2	2	4	3	1	4	5	7
54	2	2	2	2	2	1	1	2	1	2	1	4	4	3	2	2	1	3	3	1	7	3
55	2	1	1	2	1	1	2	2	2	1	1	3	4	1	3	3	3	3	2	1	4	2
56	1	2	1	2	1	2	1	2	1	2	2	4	3	3	4	1	1	4	4	4	4	1
57	1	1	1	1	2	2	2	1	2	2	1	4	3	3	1	3	4	1	3	3	8	2
58	1	1	1	1	1	1	2	2	2	1	2	3	3	4	3	1	1	2	3	2	3	3
59	2	2	2	2	2	2	2	1	1	1	1	2	3	2	3	1	4	2	1	3	4	7
60	2	1	1	2	1	2	1	1	1	1	1	4	2	4	3	3	1	4	1	2	5	5
61	1	2	1	2	2	2	2	2	2	1	1	4	1	1	2	3	2	4	3	2	6	7
62	2	2	1	1	2	2	2	2	1	2	2	1	3	4	3	2	3	3	3	4	6	5
63	2	1	1	2	1	1	2	2	1	2	1	2	1	1	2	4	4	1	3	4	3	1
64	1	1	2	2	2	1	1	1	2	2	2	1	4	4	4	3	2	1	3	2	4	6

Appendix C. Nlogit commands

C.1 Urban mobility hub choice

MNL model

```
Reset $
import;file="H:\My Drive\Graduation thesis\Data\UrbanNlogit.csv"$


Create;age18=con*age_18;age35=con*age_35;
age55=age_55*con;educationlow=edul*con;educationmid=edum*con;
workingp=Working*con; male=con*gender_m; lowinc=inclow*con;
midinc=incmid*con; highinc=inchigh*con;
kids=hh_kids*con;driv1=driver1*con;driv3=driver3*con; car1=nrcar_1*con;
car2=nrcar_2*con; privcar=carpriva*con;
passe1=pass1*con; passe2=pass2*con; bikefu=fambikeu*con;
bikefn=fambike*con; subov=ovcards*con; ov=ovcard*con;
lowedu=edul*con; midedu=edum*con$


clogit;
choices=1, 2;
lhs=chosen, nalt;
rhs=con, sun, purwork, parkh0, superm, room, parcel, gym, drugst, office,
daycare, otshop, otpack, otmeet, odcar_3, Odcar_7, Odcar_11, OH05, OH1,
OH15, TT1, TT3, TT5, Parks, age18, age35, age55, lowedu, midedu, male,
workingp, lowinc, midinc, highinc, kids, driv1, driv3, car1, car2, privcar,
passe1, passe2, bikefu, bikefn, subov, ov$
```

Random parameter mixed logit model for panel data (fixed number of observations per respondent)

```
Rplogit;
choices=1, 2;
lhs=chosen, nalt;
rhs=con, sun, purwork, parkh0, superm, room, parcel, gym, drugst, office,
daycare, otshop, otpack, otmeet, odcar_3, Odcar_7, Odcar_11, OH05, OH1,
OH15, Parks,TT1, TT3, TT5,
age18, age35, age55, lowedu, midedu, male, workingp, lowinc, midinc,
highinc, kids, driv1, driv3, car1, car2, privcar, passe1, passe2, bikefu,
bikefn, subov, ov;
Pds=8;
Draws=50;
Halton;
Fcn=otshop(n), otpack(n), otmeet(n), purwork(n), con(n)$
```

C.2 Regional mobility hub choice

MNL model

```
Reset $
import;file="H:\My Drive\Graduation thesis\Data\Nlogit
data\RegionalNlogit.csv"$

Create;age18=con*age_18;age35=con*age_35;
age55=age_55*con;educationlow=edul*con;educationmid=edum*con;
workingp=Working*con; male=con*gender_m; lowinc=inclow*con;
midinc=incmid*con; highinc=inchigh*con;
kids=hh_kids*con;driv1=driver1*con;driv3=driver3*con; car1=nrcar_1*con;
car2=nrcar_2*con; privcar=carpriva*con;
```

```
passe1=pass1*con; passe2=pass2*con; bikefu=fambikeu*con;
bikefn=fambike*con; subov=ovcards*con; ov=ovcard*con;
lowedu=edul*con; midedu=edum*con$


clogit;
choices=1,2;
lhs=chosen, nalt;
rhs=con, sun, purwork, parkh0, superm, room, parcel, gym, drugst, office,
daycare, otshop, otpack, otmeet, ROH, Parks, rodcar10, rodcar25,
rodcar40,TT1, TT3, TT5,
age18, age35, age55, lowedu, midedu, male, workingp, lowinc, midinc,
highinc, kids, driv1, driv3, car1, car2, privcar, passe1, passe2, bikefu,
bikefn, subov, ov$
```

Random parameter mixed logit model for panel data (fixed number of observations per respondent)

```
Rplogit;
choices=1,2;
lhs=chosen, nalt;
rhs=con, sun, purwork, parkh0, superm, room, parcel, gym, drugst, office,
daycare, otshop, otpack, otmeet, ROH, TT1, TT3, TT5, Parks, rodcar10,
rodcar25, rodcar40,
age18, age35, age55, lowedu, midedu, male, workingp, lowinc, midinc,
highinc, kids, driv1, driv3, car1, car2, privcar, passe1, passe2, bikefu,
bikefn, subov, ov;

Pds=8;
Draws=50;
Halton;
Fcn=otshop(n), otpack(n), otmeet(n), purwork(n), con(n)$
```

C.3 Transportation mode choice at urban mobility hub

MNL model

```
Reset $
import;file="H:\My Drive\Graduation thesis\Data\Nlogit
data\TP_UrbanNogit.csv"$

#Create interaction for attributes
Create;
con11=con1*multi; con21=con2*multi; con31=con3*multi;
rtimetr=rtimetra*multi; rtimebi=rtimebik*multi;
rtimesc=rtimesco*multi;rtimeca=rtimecar*multi; rpbik=rpbike*multi;
rpscoo=rpscoot*multi; rpca=rpcar*multi; rptrai=rptrain*multi$
Create;freq21=frequenc*multi$


#Create interactions with constant 1, bike
Create;
age181=con1*age_18;
age351=con1*age_35;age551=age_55*con1;edulow1=edul*con1; edumid1=edum*con1;
Male1=con1*gender_m; lowinc1=inclow*con1; midinc1=incmid*con1;
highinc1=inchigh*con1; kids1=hh_kids*con1;
Bikefu1=fambikeu*con1; bikefn1=fambike*con1; subov1=ovcards*con1;
ov1=ovcard*con1$
```

```
#Create interactions with constant 2, scooter

Create;
age182=con2*age_18;
age352=con2*age_35;age552=age_55*con2;edulow2=edul*con2; edumid2=edum*con2;
Male2=con2*gender_m; lowinc2=inclow*con2; midinc2=incmid*con2;
highinc2=inchigh*con2; kids2=hh_kids*con2;
Bikefu2=fambikeu*con2; bikefn2=fambike*con2; subov2=ovcards*con2;
ov2=ovcard*con2$

#Create interactions with constant 3, car
Create;
age183=con3*age_18;
age353=con3*age_35;age553=age_55*con3;edulow3=edul*con3; edumid3=edum*con3;
male3=con3*gender_m; lowinc3=inclow*con3; midinc3=incmid*con3;
highinc3=inchigh*con3; kids3=hh_kids*con3;
Bikefu3=fambikeu*con3; bikefn3=fambike*con3; subov3=ovcards*con3;
ov3=ovcard*con3$

#simple mnl

clogit;
choices=4,1,2,3;
lhs=chosen, nalt;
rhs= con1, con2, con3, Utimebus, utimebik, utimesco, utimecar, upbike,
upscoot, upcar, upbus, freq2,
age181, age351, age551, male1, lowinc1, midinc1, highinc1, kids1, bikefu1,
bikefn1, subov1, ov1,
age182, age352, age552, male2, lowinc2, midinc2, highinc2, kids2, bikefu2,
bikefn2, subov2, ov2,
age183, age353, age553, male3, lowinc3, midinc3, highinc3, kids3, bikefu3,
bikefn3, subov3, ov3
```

Random parameter mixed logit model for panel data (variable number of observations per respondent)

```
Rplogit;
choices=1, 2, 3, 4;
lhs=chosen, nalt;
rhs=con1, con2, con3, Utimebus, utimebik, utimesco, utimecar, upbike,
upscoot, upcar, upbus, freq2,
age181, age351, age551, male1, lowinc1, midinc1, highinc1, kids1, bikefu1,
bikefn1, subov1, ov1,
age182, age352, age552, male2, lowinc2, midinc2, highinc2, kids2, bikefu2,
bikefn2, subov2, ov2,
age183, age353, age553, male3, lowinc3, midinc3, highinc3, kids3, bikefu3,
bikefn3, subov3, ov3;

pds=nrchoice;
draws=25;
halton;
fcn=con1(n), con2(n), con3(n), utimebus(n), utimebik(n), utimesco (n),
utimecar(n), upbike(n), upscoot(n), upcar(n), upbus(n)$
```

C.4 Transportation mode choice at regional mobility hub

MNL

```
Reset $
```

```
import;file="H:\My Drive\Graduation thesis\Data\Nlogit
data\TP_RegionalNlogit.csv"$

#Create interaction for attributes
Create;
con11=con1*multi; con21=con2*multi; con31=con3*multi;
rtimetr=rtimetra*multi; rtimebi=rtimebik*multi;
rtimesc=rtimesco*multi;rtimeca=rtimecar*multi; rpbik=rpbike*multi;
rpscoo=rpscoot*multi; rpca=rpcar*multi; rptrai=rptrain*multi$
Create;freq21=frequenc*multi$


#Create interactions with constant 1, bike
Create;
age181=con1*age_18;
age351=con1*age_35;age551=age_55*con1;edulow1=edul*con1; edumid1=edum*con1;
Male1=con1*gender_m; lowinc1=inclow*con1; midinc1=incmid*con1;
highinc1=inchigh*con1; kids1=hh_kids*con1;
Bikefu1=fambikeu*con1; bikefn1=fambike*con1; subov1=ovcards*con1;
ov1=ovcard*con1$

#Create interactions with constant 2, scooter

Create;
age182=con2*age_18;
age352=con2*age_35;age552=age_55*con2;edulow2=edul*con2; edumid2=edum*con2;
Male2=con2*gender_m; lowinc2=inclow*con2; midinc2=incmid*con2;
highinc2=inchigh*con2; kids2=hh_kids*con2;
Bikefu2=fambikeu*con2; bikefn2=fambike*con2; subov2=ovcards*con2;
ov2=ovcard*con2$

#Create interactions with constant 3, car
Create;
age183=con3*age_18;
age353=con3*age_35;age553=age_55*con3;edulow3=edul*con3; edumid3=edum*con3;
male3=con3*gender_m; lowinc3=inclow*con3; midinc3=incmid*con3;
highinc3=inchigh*con3; kids3=hh_kids*con3;
Bikefu3=fambikeu*con3; bikefn3=fambike*con3; subov3=ovcards*con3;
ov3=ovcard*con3$

#simple mnl

clogit;
choices=4,1,2,3;
lhs=chosen, nalt;
rhs= con1, con2, con3, rtimetra, rtimebik, rtimesco, rtimecar, rpbike,
rpscoot, rpcar, rptrain, frequenc,
age181, age351, age551, male1, lowinc1, midinc1, highinc1, kids1, bikefu1,
bikefn1, subov1, ov1,
age182, age352, age552,  male2, lowinc2, midinc2, highinc2, kids2, bikefu2,
bikefn2, subov2, ov2,
age183, age353, age553,  male3, lowinc3, midinc3, highinc3, kids3, bikefu3,
bikefn3, subov3, ov3
$
```

Random parameter mixed logit model for panel data (variable number of observations per respondent)

```
#mixed logit with variable panel
Rplogit;
```

```
choices=1, 2, 3, 4;
lhs=chosen, nalt;
rhs=con1, con2, con3, rtimetra, rtimebik, rtimesco, rtimecar, rpbike,
rpscoot, rpcar, rptrain, frequenc,
age181, age351, age551, male1, lowinc1, midinc1, highinc1, kids1, bikefu1,
bikefn1, subov1, ov1,
age182, age352, age552,  male2, lowinc2, midinc2, highinc2, kids2, bikefu2,
bikefn2, subov2, ov2,
age183, age353, age553,  male3, lowinc3, midinc3, highinc3, kids3, bikefu3,
bikefn3, subov3, ov3;

pds=nrchoice;
draws=50;
halton;
fcn=con1(n), con2(n), con3(n), rtimetra(n), rtimebik(n), rtimesco(n),
rtimecar(n), rpbike(n), rpscoot(n), rpcar(n), rptrain(n)$
```

Appendix D. MNL model with interaction effects

Hub choice

Table 16 MNL model with interaction effects for hub choice

			Coefficients MNL with interaction			
	Variable	**Variable levels**	**Urban parameters**	**Std. Error**	**Regional parameters**	**Std. Error**
HUB	**Constant**		-2.19***	0.163	-2.191***	0.203
	Weather	Sun	0.225***	0.040	0.224***	0.043
		Rain	-0.225		-0.224	
	Primary travel purpose	Work	-0.032	0.041	-0.032	0.044
		Leisure	0.032		0.032	
	Other activities	Grocery shopping	-0.007	0.070	0.101	0.073
		Picking up a package	0.057	0.069	-0.094	0.076
		Business meeting	0.332***	0.068	0.244***	0.072
		Bringing and picking up children from daycare	-0.382		-0.251	
	Travel distance origin-hub				-0.001	0.006
		0.5 kilometer	0.049	0.070		
		1 kilometer	-0.019	0.071		
		1.5 kilometer	-0.047	0.071		
		2 kilometer	0.017			
	Transfer time	1 minute	0.052	0.069	-0.159*	0.078
		3 minutes	-0.015	0.071	-0.069	0.079
		5 minutes	0.054	0.070	0.106	0.078
		7 minutes	-0.091		0.122	
	Parking price at the hub	0 euros	0.163***	0.041	0.005	0.043
		8 euros	-0.163		-0.005	
	Supermarket	Yes	0.005	0.041	0.168***	0.044
		No	-0.005		-0.168	
	Parcel pick-up point	Yes	0.041	0.041	0.018	0.044
		No	-0.041		-0.018	
	Café	Yes	-0.018	0.041	0.105*	0.043
		No	0.018		-0.105	
	Daycare	Yes	0.016	0.041	0.012	0.044
		No	-0.016		-0.012	
	Gym	Yes	0.016	0.040	0.067	0.043
		No	-0.016		-0.067	
	Drug store/medicine pick-up point	Yes	-0.017	0.041	-0.089*	0.043
		No	0.017		0.089	

	Social extended reality office space	Yes	0.136***	0.041	0.111**	0.044
		No	-0.136		-0.111	
STATUS QUO	**Parking price for the status quo**		-0.061***	0.006	-0.055***	0.007
	Distance to be covered by own car in status quo	3/10 kilometer	-0.496***	0.067	-0.275***	0.072
		7/25 kilometer	-0.042	0.070	-0.038	0.075
		11/40 kilometer	0.089	0.071	0.274***	0.079
		15/55 kilometer	0.449		0.039	
HUB	**Gender**	Male	0.025	0.045	-0.051	0.050
		Female	-0.025		0.05	
	Age	18-34 years	0.045	0.098	0.134	0.107
		35-54 years	0.146*	0.072	0.157*	0.075
		55-64 years	-0.236**	0.077	-0.231***	0.080
		65 years and older	0.031		-0.06	
	Income	Low	-0.426*	0.203	-0.427	0.238
		Middle	0.13	0.133	0.442**	0.146
		High	0.003	0.256	-0.031	0.248
		No information	0.293		0.016	
	Education	Low	-0.564***	0.100	-0.058	0.098
		Middle	0.405***	0.067	-0.017	0.069
		High	0.159		0.075	
	Employment status	Working	0.100*	0.047	0.116*	0.051
		Non-working	-0.1		-0.116	
	Household	With kids	0.110*	0.049	-0.062	0.051
		Without kids	-0.11		0.062	
	Number of cars in the household	1 car	0.368***	0.084	0.147	0.089
		2 cars	0.012	0.087	-0.244**	0.093
		3 cars or more	-0.38		0.097	
	#Driving a car per week	1-2 days a week	0.358***	0.064	0.129	0.067
		3-4 days a week	0.096	0.058	0.016	0.064
		5 days a week or more	-0.454		-0.145	
	#As passenger in the car	Less than one day per week	-0.495***	0.064	-0.085	0.066
		1-2 days per week	0.292***	0.060	0.135*	0.066
		3 days per week or more	0.203		-0.05	
	Ownership of the car	Private car	0.167	0.089	0.177	0.114

		Lease car from work	-0.167		-0.177	
	OV-card ownership	With subscription	0.362***	0.069	0.461***	0.067
		Without subscription	-0.012	0.059	-0.042	0.062
		No card	-0.35		-0.419	
	Familiarity with shared bike	Yes and use it	0.052	0.110	0.437***	0.109
		Yes but do not use it	-0.149*	0.068	-0.324***	0.069
		No	0.097		-0.113	
STATUS QUO	**Interaction effects**	Low income * Parking price status quo	-0.008	0.011	-0.004	0.012
		Middle income * Parking price status quo	0.005	0.007	0.007	0.008
		High income * Parking price status quo	-0.005	0.014	-0.001	0.013
		No info income * Parking price status quo	0.008		-0.002	
HUB	**Interaction effects**	Household with kids * Daycare facility	0.042	0.041	0.023	0.044
		Household without kids * Daycare facility	-0.042		-0.023	
		Working people * Office facility	0.06	0.041	0.038	0.043
		Non-working people * Office facility	-0.06		-0.038	
	Model fit	LL(0)	-2500.9		-2622.9	
		LL(β)	-1876.8		-1731.4	
		R^2	0.250		0.340	
		Adjusted R^2	0.244		0.335	

*Note. *p<.05, **p<.01, ***p<.001.*

Transportation mode choice

Urban hub

Table 17 Results MNL model with interactions for transportation mode choice at urban hub

		Coefficients of MNL model with interactions - Transportation mode choice urban hub							
Variable	**Variable level**	**Alternative 1: Bus**	**Std. error**	**Alternative 2: Shared bike**	**Std. error**	**Alternative 3: Shared scooter**	**Std. error**	**Alternative 4: Shared car**	**Std. error**
Constant		0		-0.1	0.52	-3.111***	0.860	-0.315	0.456
Travel time		0.006	0.071	-0.003	0.05	0.031	0.048	-0.045	0.084
Total price		-0.043	0.161	0.003	0.06	-0.035	0.103	0.016	0.057
Arrival frequency		0.027	0.065	-		-		-	
Gender	Male	0		-0.189**	0.07	-0.071	0.149	-0.077	0.099
	Female	0		0.189		0.071		0.077	
Age	18-34 years	0		0.923	0.57	1.762*	0.823	1.537*	0.611
	35-54 years	0		-1.237**	0.41	0.072	0.652	-1.594***	0.469
	55-64 years	0		0.904*	0.53	0.078	0.994	0.983*	0.561
	65 years and older	0		-0.59		-1.912		-0.926	
Income	Low	0		-0.104	0.64	-0.519	1.151	-0.346	0.698
	Middle	0		-0.275	0.45	0.197	0.782	-0.698	0.481
	High	0		0.056	0.92	-0.937	1.818	0.551	0.908
	No information	0		0.323		1.259		0.493	
Household	With kids	0		0.166*	0.08	0.377*	0.170	-0.012	0.108
	Without kids	0		-0.166		-0.377		0.012	
Familiarity with shared bike	Yes and use it	0		-0.165	0.19	0.482	0.279	0.212	0.237
	Yes but do not use it	0		0.318**	0.12	0.005	0.204	0.201	0.151
	No	0		-0.153		-0.487		-0.413	
OV-card ownership	With subscription	0		-0.229*	0.11	-0.297	0.226	-0.636***	0.157
	Without subscription	0		-0.153	0.1	-0.105	0.210	0.369**	0.131
	No card	0		0.382		0.402		0.267	
Interaction effects	Income low * price	-0.175	0.206	-0.115	0.08	-0.075	0.115	-0.605	0.064
	Income middle * price	-0.089	0.144	-0.036	0.05	-0.041	0.074	-0.014	0.044
	Income high * price	0.093	0.291	0.12	0.1	0.093	0.162	0.059	0.078
	No information * price	0.171		0.031		0.023		0.56	
	18-34 years * price	0.131	0.182	-0.036	0.07	-0.034	0.079	-0.064	0.061
	35-54 years * price	**-0.265***	0.129	-0.022	0.05	-0.079	0.063	0.035	0.042
	55-64 years * price	0.157	0.173	-0.012	0.07	0.043	0.098	0.011	0.055
	65 years and older * price	-0.023		0.07		0.07		0.018	
Model fit	LL(0)	-1523.5							
	LL(β)	-1214.6							
	R^2	0.203							
	Adjusted R^2	0.196							

*Note. *p<.05, **p<.01, ***p<.001.*

Regional hub

Table 18 Results MNL model with interactions for transportation mode choice at regional hub

		Coefficients of MNL model with interactions - Transportation mode choice regional hub							
Variable	**Variable level**	**Alternative 1: Train**	**Std. error**	**Alternative 2: Shared bike**	**Std. error**	**Alternative 3: Shared scooter**	**Std. error**	**Alternative 4: Shared car**	**Std. error**
Constant		0		-1.153**	0.38	-0.07	1.04	0.063	0.44
Travel time		-0.569***	0.16	-0.12**	0.03	-0.116**	0.04	-0.372**	0.12
Total price		0.008	0.08	0.03	0.04	-0.335	0.21	-0.124**	0.04
Arrival frequency		0.069	0.08						
Gender	Male	0		-0.181	0.12	0.166	0.19	0.069	0.12
	Female	0		0.181		-0.166		-0.069	
Age	18-34 years	0		0.168	0.60	0.472	0.77	0.235	0.68
	35-54 years	0		-0.048	0.37	-0.463	0.50	-0.15	0.37
	55-64 years	0		0.471	0.44	-0.718	0.70	-0.046	0.45
	65 years and older	0		-0.591		0.709		-0.039	
Income	Low	0		0.128	0.66	0.969	1.21	0.349	0.63
	Middle	0		-0.015	0.40	-1.574	1.05	-0.317	0.40
	High	0		-0.433	0.70	-3.424*	1.72	0.534	0.81
	No information	0		0.32		4.029		-0.566	
Household	With kids	0		0.329**	0.12	0.578**	0.18	0.207	0.12
	Without kids	0		-0.329		-0.578		-0.207	
Familiarity with shared bike	Yes and use it	0		0.994***	0.21	0.613***	0.30	-0.083	0.32
	Yes but do not use it	0		-0.842***	0.16	-1.204***	0.25	-0.199	0.19
	No	0		-0.152		0.591		0.282	
OV-card ownership	With subscription	0		-0.477***	0.16	-0.451*	0.26	-0.907***	0.18
	Without subscription	0		0.103	0.15	-0.008	0.24	0.183	0.15
	No card	0		0.374		0.459		0.724	
Interaction effects	Income low * price	-0.03	0.11	-0.001	0.05	0.197	0.21	-0.013	0.05
	Income middle * price	-0.065	0.07	-0.041	0.03	0.285	0.20	0.011	0.03
	Income high * price	0.07	0.13	0.06	0.06	0.32	0.22	-0.056	0.07
	No information * price	0.025		-0.018		-0.802		0.058	
	18-34 years * price	0.074	0.11	-0.004	0.05	-0.042	0.06	-0.021	0.05
	35-54 years * price	0.02	0.06	0.001	0.03	0.032	0.03	0.008	0.03
	55-64 years * price	-0.07	0.08	-0.039	0.04	-0.008	0.05	-0.019	0.03
	65 years and older * price	0.261		0.042		0.018		0.032	
Model fit	LL(0)	-1110.4							
	LL(β)	-764.82							
	R^2	0.311							
	Adjusted R^2	0.306							

*Note. *p<.05, **p<.01, ***p<.001.*

Appendix E. Survey

Part 1: Privacybeleid

Geachte heer/mevrouw,

Bedankt dat u deze vragenlijst wil invullen! Mijn naam is Marise Zuurbier en deze vragenlijst is deel van mijn afstudeerproject voor de master Construction Management & Engineering aan de Technische Universiteit Eindhoven (TU/e). Het doel van dit onderzoek is om inzicht te krijgen in de toekomst van de mobiliteitshub. Verderop in deze vragenlijst zal dit concept verder uitgelegd worden.

Het invullen van de vragenlijst zal u ongeveer 12 tot 15 minuten kosten. Uw antwoorden worden anoniem opgeslagen en het is belangrijk om te weten dat u vrijwillig meedoet en u altijd kan stoppen met deze vragenlijst zonder opgave van reden. Het onderzoek volgt de veiligheidsrichtlijnen van de TU/e.

Bij vragen kunt u altijd contact opnemen met mij via m.n.zuurbier@student.tue.nl. Nogmaals bedankt voor uw deelname aan mijn onderzoek!

Met vriendelijke groet,

Marise Zuurbier

Door dit toestemmingsformulier te ondertekenen erken ik het volgende:

1. Ik ben voldoende geïnformeerd over het onderzoek door middel van een separaat informatieblad. Ik heb het informatieblad gelezen en heb daarna de mogelijkheid gehad vragen te kunnen stellen. Deze vragen zijn voldoende beantwoord.

2. Ik neem vrijwillig deel aan dit onderzoek. Er is geen expliciete of impliciete dwang voor mij om aan dit onderzoek deel te nemen. Het is mij duidelijk dat ik deelname aan het onderzoek op elk moment, zonder opgaaf van reden, kan beëindigen. Ik hoef een vraag niet te beantwoorden als ik dat niet wil.

Daarnaast geef ik toestemming voor de volgende onderdelen van het onderzoek:

3. Ik geef toestemming om de persoonsgegevens die gedurende het onderzoek bij mij worden verzameld te verwerken zoals is opgenomen in het informatieblad.

4. Ik geef toestemming om de bij mij verzamelde onderzoeksdata te bewaren en te gebruiken voor toekomstig onderzoek op het gebied van mobiliteitshubs waarbij erkende ethische normen voor wetenschappelijk onderzoek in acht worden genomen, en voor onderwijsdoeleinden.

Voor de volledige informatie verwijs ik u naar *hier*.

Ik ga akkoord met het data en privacy beleid van dit onderzoek ☐

Part 2: Introductievragen/screening

1. Bent u in het bezit van een rijbewijs?
    a. Ja
    b. Nee

2. Hoeveel private auto's bezit uw huishouden?
    a. 0
    b. 1
    c. 2
    d. 3 of meer

3. Hoe vaak gebruikt u de auto als bestuurder?
    a. 5 dagen per week of meer
    b. 3-4 dagen per week
    c. 1-2 dagen per week
    d. 2-3 dagen per maand
    e. 1 dag per maand
    f. Nooit of bijna nooit

Part 3: Private vervoersmiddelen

4. Welk van de volgende micromobiliteitsvervoersmiddelen zijn aanwezig in uw huishouden?
    a. Reguliere fiets
    b. Elektrische fiets
    c. Racefiets
    d. Bakfiets
    e. Motorfiets
    f. (Elektrische) scooter
    g. Geen van bovenstaande

De volgende vragen gaan over (het bezit van) een private auto.

5. In wat voor soort bezit is de auto die u het meeste gebruikt?
    a. Privé auto
    b. Private lease auto
    c. Lease auto van werk
    d. Anders

6. Wat voor aandrijfvorm heeft de auto die u het meeste gebruikt?
    a. Benzine
    b. Diesel
    c. LPG
    d. Elektrisch
    e. Hybride

f. Plug-in hybride
g. Anders

7. Hoe vaak zit u in de auto als passagier?
    a. 5 dagen per week of meer
    b. 3-4 dagen per week
    c. 1-2 dagen per week
    d. 2-3 dagen per maand
    e. 1 dag per maand
    f. Nooit of bijna nooit

8. Voor welke doeleinden gebruikt u de auto? Selecteer maximaal 4 doeleinden.
    a. Van en naar werk
    b. Onderwijs/cursus volgen
    c. Winkelen/boodschappen doen
    d. Sport/hobby
    e. Visite/logeren
    f. Toeren/wandelen
    g. Overige vrijetijdsbesteding
    h. Afhalen/brengen goederen
    i. Afhalen/brengen personen
    j. Beroepsmatig
    k. Diensten/persoonlijke verzorging
    l. Zakelijk bezoek in werksfeer
    m. Ander motief
    n. Niet van toepassing

Part 4: Collectieve vervoersmiddelen

De volgende vragen gaan over collectieve vervoersmiddelen. U betaalt voor deze transportmiddelen een bepaalde prijs per rit in plaats van dat u het vervoersmiddel daadwerkelijk bezit.

9. Bent u in het bezit van een persoonlijke OV chipkaart?
    a. Ja en ik heb een abonnement (bv. Business kaart, traject vrij, dalurenkorting, studenten OV, etc.)
    b. Ja maar ik heb geen abonnement
    c. Nee

10. Ben u bekend met het concept van de gedeelde elektrische fiets?
    a. Ja en ik maak er (soms) gebruik van
    b. Ja maar ik gebruik het niet
    c. Nee

11. Bent u bekend met het concept van de gedeelde elektrische scooter?
    a. Ja en ik maak er (soms) gebruik van

b. Ja maar ik gebruik het niet
c. Nee

12. Bent u bekend met het concept van de gedeelde auto?
    a. Ja en ik maak er (soms) gebruik van
    b. Ja maar ik gebruik het niet
    c. Nee

13. Hoe lang duurt het om vanuit thuis naar de dichtstbijzijnde openbaar vervoer halte (bijv. bus, tram, metro) te lopen?
    a. 1-5 minuten
    b. 6-10 minuten
    c. 11-20 minuten
    d. 21-30 minuten
    e. 31 minuten of meer

14. Hoe lang duurt het om vanuit thuis naar de dichtstbijzijnde openbaar vervoer halte (bijv. bus, tram, metro) te fietsen?
    a. 1-5 minuten
    b. 6-10 minuten
    c. 11-20 minuten
    d. 21-30 minuten
    e. 31 minuten of meer

15. Hoe lang duurt het om vanuit thuis naar de dichtstbijzijnde treinstation te lopen?
    a. 1-5 minuten
    b. 6-10 minuten
    c. 11-20 minuten
    d. 21-30 minuten
    e. 31 minuten of meer

16. Hoe lang duurt het om vanuit thuis naar de dichtstbijzijnde treinstation te fietsen?
    a. 1-5 minuten
    b. 6-10 minuten
    c. 11-20 minuten
    d. 21-30 minuten
    e. 31 minuten of meer

Part 5: Stated choice experiment

Each respondents receives 8 questions in this part. Only one question is now presented.

Dit blok geeft eerst uitleg over een aantal begrippen die gebruikt worden in dit onderzoek. Hierna wordt een voorbeeldvraag weergegeven.

In dit gedeelte van de vragenlijst staat de multimodale mobiliteitshub centraal. De multimodale mobiliteitshub, ook wel de mobiliteitshub of hub genoemd, is een plek waar op zijn minst drie vervoersmiddelen aangeboden worden. Onderstaand filmpje toont een korte visualisatie van wat een mobiliteitshub inhoudt. Het filmpje is gebaseerd op de wijkhub in metropoolregio Amsterdam. De hub in dit filmpje kan het concept van de mobiliteitshub verduidelijken.

De hub kan ook bepaalde faciliteiten aanbieden. In dit onderzoek wordt er gekeken naar de volgende faciliteiten: supermarkt, pakketjespunt (pakketautomaat), huiskamer, sportschool, drogisterij en medicijn ophaalpunt (medicijnautomaat), social extended reality kantoor en kinderdagverblijf. Het kan zijn dat een aantal van de vervoersmiddelen of faciliteiten onbekend voor u zijn. Hieronder volgt een korte uitleg.

Faciliteit	Pakketautomaat	Medicijn afhaalautomaat	Social extended reality kantoor	Huiskamer/Café
Hoe ziet het er uit				
Wat is het?	Pakketten kunnen hier afgeleverd en opgehaald worden.	Bestelde medicijnen van de apotheek kunt u hier ophalen.	Dit is een geavanceerde vorm van videobellen/digitaal vergaderen, waarbij je digitaal maar levensecht kunt vergaderen met je vrienden, familie, collega's en klanten. Stel je voor dat je voor een tafel zit, en door een speciale XR-bril te dragen, zie je je familie of vrienden digitaal voor je zitten, terwijl ze in werkelijkheid elders kunnen zijn.	Dit is een café dat op een huiskamer lijkt. Je kan er onder andere rustig zitten, een boek lezen, een kop koffie drinken, iets kleins eten of afspreken met collega's.

Vervoers middel	Gedeelde e-fiets	Gedeelde auto	Gedeelde scooter
Hoe ziet het er uit			
Wat is het?	De deelfiets kan je gebruiken om van A naar B te komen. Je kan de fiets 24 uur 'in bezit' hebben en/of na je rit achterlaten in (grote) aangewezen gebieden.	De deelauto kan je gebruiken om van A naar B te komen. Je moet de auto op de daarvoor bestemde parkeerplek parkeren op het aankomstpunt.	De deelscooter kan je gebruiken om van A naar B te komen. Je kan de scooter neerzetten in (grote) aangewezen gebieden.

U krijgt in het volgende gedeelte een aantal situaties voorgelegd. Er wordt u gevraagd in totaal 8 keer een keuze te maken welke situatie (1 of 2) u zou gebruiken om bij uw eindbestemming te komen.

- **Situatie 1** is altijd een reis die u maakt met uw **eigen** auto. Deze reis heeft bepaalde kenmerken zoals de brandstofkosten (gebaseerd op de brandstof van uw eigen auto), parkeerkosten en reistijd. In dit onderzoek gaan we ervan uit dat dit uw **initiële** reis is, **de status quo.**
- **Situatie 2** is altijd een reis die u maakt via een **mobiliteitshub**, dit is het alternatief voor reizen met uw auto. Dit beketent dat u naar de mobiliteitshub zou reizen en vanaf de mobiliteitshub een ander vervoersmiddel gebruikt om uw weg te vervolgen. Het vervoersmiddel dat u gebruikt van huis naar de hub en van de hub naar uw eindbestemming mag u zelf kiezen. Dezelfde vervoersmiddelen zijn altijd beschikbaar. Hieraan zijn variërende kosten en reistijden verbonden. Op de hub worden ook variërende faciliteiten aangeboden waar u gebruik van kunt maken als u er bent. Tot slot heeft u ook een overstaptijd op de hub. Hiermee wordt de tijd bedoeld die u nodig heeft om te lopen van het ene vervoersmiddel naar het andere.
- In beide situaties **is het doel van de reis, het weer** en de **andere activiteit** die u moet doen **hetzelfde.**

*

U moet 10 kilometer reizen voor vrijetijdsbesteding en het regent. Verder moet u die dag nog een pakketje ophalen. Zou u dan met uw eigen auto of via de hub reizen?

Situatie 1: Originele reis met eigen auto		**Situatie 2: Reizen via de hub**				
Reistijd	8 minuten	Afstand van thuis naar de hub	4 km			
Parkeerkosten	€20	Parkeerkosten als u de auto op de hub parkeert	€8			
Brandstofkosten	€1.4	Overstaptijd om bij vervoersmiddel te komen	1 minuut			
Eigen auto		**Vervoersmiddelen die u kan gebruiken**	**Trein**	**Deel e-fiets**	**Deel e-scooter**	**Deelauto**
		Reistijd van hub naar bestemming	3 minuten	16 minuten	16 minuten	5 minuten
		Kosten voor de reis	€4,30	€3,41	€5,81	€7,86
		Aantal keer aankomst per uur	4	Altijd beschikbaar	Altijd beschikbaar	Altijd beschikbaar
		Faciliteiten op de hub			**Wel (✓) of niet (-) aanwezig**	
		Supermarkt			✓	
		Pakketjes punt			-	
		Huiskamer			✓	
		Sportschool			✓	
		Drogisterij en medicijn ophaalpunt			-	
		Social extended reality kantoor			-	
		Kinderdagverblijf			-	
○		●				

Klik onderaan op het bolletje van uw voorkeur.

*U heeft aangegeven via de mobiliteitshub te reizen.Welk vervoersmiddel aangeboden op de hub zou u in deze situatie gebruiken om bij uw bestemming aan te komen?

Kies één van de volgende antwoorden

- ○ Trein
- ○ Deelfiets
- ○ Deelscooter
- ○ Deelauto

*U heeft aangegeven via de mobiliteitshub te reizen. Met welk eigen vervoersmiddel zou u vanuit thuis naar de mobiliteitshub reizen?

Kies één van de volgende antwoorden

- ○ Auto
- ○ (Elektrische) fiets
- ○ (Elektrische) scooter
- ● Lopend
- ○ Anders: [ ]

Aan sommige veroersmiddelen zijn de volgende (gemiddelde) extra brandstofkosten verbonden: auto - €0,11/km voor diesel, €0,14/km voor benzine, €0,07/km voor LPG, €0,06/km voor elektrisch, €0,08/km voor hybride, €0,09/km voor plugin hybride en scooter: €0,05/km voor benzine en €0,01/km voor elektrisch.

Part 6: Attitudes and facilities

17. Als u via een mobiliteitshub zou reizen, hoe vaak zou u de volgende faciliteiten en services gebruiken? Geef aan voor elk van de volgende faciliteiten. (Heel vaak – vaak – soms – zelden – nooit).
    a. Supermarkt
    b. Pakketjes ophaalpunt
    c. Woonkamer/plek om te zitten, koffie te drinken en werken
    d. Drogisterij/medicijn ophaalpunt
    e. Sportschool
    f. Social extended reality kantoor
    g. Kinderdagopvang

Attitude naar multimodaliteit

5-punts Likert schaal (sterk mee oneens – sterk mee eens)

18. Ik zou een of meerdere vervoersmiddelen die ik gebruik veranderen als ik hiermee tijd of geld bespaar
19. Een langere reistijd voor mijn dagelijkse trips maakt mij niet uit als het me minder geld kost
20. Ik zou geen auto in bezit hoeven te hebben als andere vervoersmiddelen makkelijk bereikbaar zijn (zoals en gedeelde auto, fiets, openbaar vervoer)

Attitude naar het milieu

5-punts Likert schaal (sterk mee oneens-sterk mee eens)

21. Het is mijn verantwoordelijkheid om actie te nemen om milieuvriendelijk te zijn
22. Ik limiteer reizen met de auto om uitstoot and luchtkwaliteit te verbeteren
23. We moeten beslissingen maken om de uitstoot van broeikasgassen te beperken
24. Ik ben bereid meer te betalen voor milieuvriendelijke producten

Part 7: Demografische vragen

25. Wat is uw geslacht?
    a. Man
    b. Vrouw
    c. Anders
    d. Zeg ik liever niet

26. Wat is uw leeftijd?
    a. 18-24 jaar
    b. 25-34 jaar
    c. 35-44 jaar
    d. 45-54 jaar
    e. 55-64 jaar
    f. 65-74 jaar
    g. 75 of ouder

27. Wat is uw meest recente persoonlijke maandelijkse netto inkomen?
    a. Minder dan 833 euro
    b. 833 tot 1667 euro
    c. 1667 tot 2500 euro
    d. 2500 tot 3333 euro
    e. 3333 euro tot 4167 euro
    f. 4167 euro of meer
    g. Weet ik niet

28. Wat is uw huidige werksituatie?
    a. Fulltime (36 uur+) dienstverband
    b. Parttime (0-36 uur) dienstverband
    c. Werkloos
    d. Zelfstandig ondernemer
    e. Student
    f. Gepensioneerd
    g. Anders

29. Wat is uw hoogst voltooide opleiding? Dit is de opleiding waarvan u een diploma heeft behaald.
    a. Basisonderwijs, lager onderwijs
    b. Lager beroepsonderwijs of vmbo, vbo, lwoo, vso, vglo, mavo, ulo, mulo
    c. Middelbaar beroepsonderwijs of havo, atheneum, gymnasium, mms, hbs
    d. Hoger beroepsonderwijs, Universiteit
    e. Andere opleiding

30. Hoe ziet uw huishouden eruit?
    a. Eenpersoonshuishouden
    b. Paar
    c. Paar + thuiswonende kind(eren)
    d. Paar + thuiswonende kind(eren) + ander(en)
    e. Paar + ander(en)
    f. Eenouderhuishouden + thuiswonende kind(eren)
    g. Eenouderhuishouden + thuiswonende kind(eren) + ander(en)
    h. Overig huishouden

31. Als u een of meer kinderen heeft die thuis wonen, hoe oud zijn zij?
    a. 0-4 jaar
    b. 5-12 jaar
    c. 13-18 jaar
    d. 19 jaar of ouder
    e. Niet van toepassing

Dit waren alle vragen. Bedankt voor het invullen van de vragenlijst. Als u vragen heeft, kunt u contact opnemen met Marise Zuurbier via m.n.zuurbier@student.tue.nl.