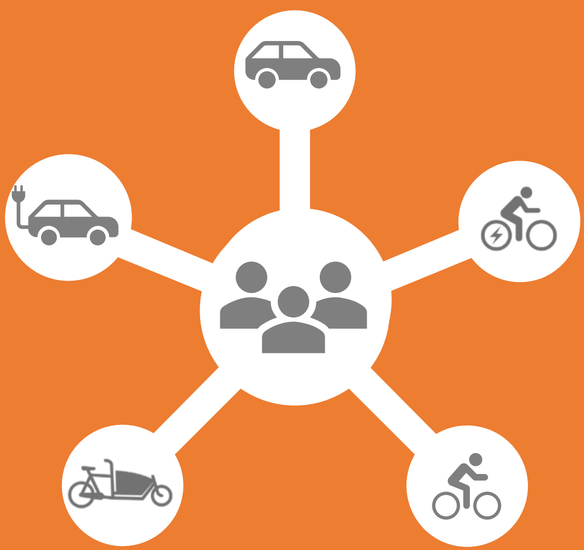
Ex-post evaluation of neighbourhood shared mobility hubs

A qualitative research on the factors influencing the usage and effects of mobility hubs

Iris van Gerrevink



Ex-post evaluation of neighbourhood shared mobility hubs

A qualitative research on the factors influencing the usage and effects of mobility hubs

Master thesis report

by

Iris van Gerrevink

to obtain the degree of Master of Science in
Transport, Infrastructure and Logistics

at the Delft University of Technology,
to be defended publicly on Monday August 2, 2021

July 2021

Student number	4484231	
Thesis committee:	Prof. dr. G.P. van Wee	TU Delft - chair
	Dr. J.A. Annema	TU Delft - supervisor
	Dr. Ir. N. van Oort	TU Delft - supervisor
	Ir. J. de Jong	Arcadis - external supervisor

Preface

This thesis, “Ex-post evaluation of neighbourhood shared mobility hubs“ is written as a final step to complete my master program Transport, Infrastructure and Logistics at the TU Delft. This thesis presents my work from the last six months during my graduation internship at Arcadis. I have really enjoyed diving into the subject of mobility hubs. I have always been interested in mobility and especially sustainable mobility. When I first came across the concept of a mobility hub, I immediately became curious and enthusiastic. I noticed a lot of high expectations for a mobility hub to contribute to the liveability in cities and the challenge of the mobility transition. While I did (and still do) believe in the potential of mobility hubs, I saw that there were still many things to research. Which led to the thesis in front of you!

I want to thank Arcadis for the opportunity to conduct this research at Arcadis, albeit mostly from home due to the corona pandemic. I am grateful to my supervisor Joost de Jong for our weekly meetings, his involvement and always willing to help. I would also like to thank my daily TU Delft supervisors, Jan Anne Annema and Niels van Oort for their valuable feedback and always making time. Though we did not meet often, also Bert van Wee, as the chair of my thesis committee, has provided very useful and detailed comments on my thesis.

Next, I want to express my gratitude towards my (study)friends, family, and boyfriend for their support, not only during this thesis research but for my entire study career. Thanks for the fun times, positivity, and all other support!

I am very curious about the developments of how mobility hubs and will definitely stay involved!

Iris van Gerrevink,
Delft, July 2021

Summary

Situation

The world's population is steadily increasing, and more specifically, cities are growing significantly by the rising share of people residing in urban areas. This also brings extensive activities, leading to multiple advantages but also problems. Many people living on a small surface area and the emerging awareness and reality of climate change, make that changes in the current way of transport and mobility are required. Therefore, cities are taking several (transport) policy actions to reduce the need to travel, make travel more sustainable or increase efficiency. In that light, one of the promising concepts gaining more attention in recent years is the development of shared mobility. The shared use of a transportation service may reduce the need to own a vehicle, which is not only an environmental burden but also takes up a lot of (public) space. Even more recently, 'mobility hubs' are becoming more popular. A mobility hub is defined as a place where several (shared) transport modalities are combined. Several Dutch municipalities are currently realising mobility hubs as they perceive they can deliver a significant contribution to the required mobility transition. Because they can offer alternatives to conventional disadvantageous travel choices and make sustainable travel forms more attractive.

Research objective

This thesis' objective is to perform explorative qualitative research on the opportunities and effectiveness of neighbourhood mobility hubs in the Netherlands. From literature research, it followed that there is little scientific research available on the general topic of (neighbourhood) mobility hubs. Moreover, the limited available literature and non-scientific studies are predominantly ex-ante studies, focussing on the potential of mobility hubs. No ex-post evaluation has been done on the actual effects and contributions of a mobility hub. And this evaluation is not only relevant from a scientific point of view, but also municipalities are expressing the need for more knowledge. Thirdly, previous research has stated that there is potential to explore further the governance process and government policies of shared mobility and mobility hubs.

To evaluate the effectiveness and make recommendations on improving the effectiveness in the future, it is crucial to understand the factors that contribute to, or withhold, these (positive) effects. This research, therefore, aims to answer the research question:

Which factors have influenced the usage and the effects, regarding shared mobility and mobility hub municipal policy goals, of existing neighbourhood mobility hubs?

Three sub-questions were formulated to answer the main research question: 1) What are the municipal policy goals for shared mobility and mobility hubs, and how can a mobility hub be assessed? 2) What are the factors explaining the usage and effects of neighbourhood mobility hubs in literature? 3) To what extent does practice confirm the usage factors and effects, of neighbourhood mobility hubs, obtained from literature research?

Methodology

A qualitative and explorative approach is taken to find influencing factors of mobility hub usage and effects. A qualitative approach fits the objective well. Due to the mobility system's dynamics, complexity, and to provide a better high-level understanding of these factors. Besides, quantitative research is estimated to not be feasible and scientifically sound at this moment. Neighbourhood mobility hubs (in the Netherlands) are a relative novelty. (Open) quantitative data is unavailable, and the uncertain precise impact of the COVID-19 pandemic in the field of mobility plays a role. All things considered, this research is primarily based on three qualitative research methodologies: literature research, qualitative causal loop diagram, and interviews.

Results

Societal goals and ambitions of mobility hubs are analysed to establish criteria for the ex-post evaluation. This is the first research step related to the first sub research question. For this purpose, policy documents were used of Dutch municipalities, which are either one of the largest municipalities and/or have a mobility hub. This analysis shows that while 'shared mobility' is an often described subject, it is not always linked to policy goals. Mobility hubs, specifically, are even covered less often. However, mobility hubs can be seen as an enabler of shared mobility goals; therefore, these goals can be indirectly linked to mobility hubs. In the identified statements for the policy documents, there are four main themes distinguishable: (1) public space improvement, (2) sustainable and liveable environment, (3) reduction of (private) car usage and ownership, (4) improvement of accessibility. These four themes have formed the basis for assessing and evaluating the effectiveness of neighbourhood mobility hubs.

A literature review has gained insights into the second sub-question regarding the factors that explain the usage and effects of neighbourhood mobility hubs. First, there is started to specifically look into mobility hub researches. But as these are limited (scoped to station-based shared mobility usage factors and impacts on the environment, built environment, and travel behaviour), the literature research has expanded to general shared mobility usage and effects. The literature review has given insight into a series of factors and different aspects that affect the usage and the impact of shared mobility. It has been made clear that all influencing variables and interconnections make a complex system. Nevertheless, various scientific papers have gained insights into the separate shared modalities and their effects, based on the four policy goals, their dependent variables and correlations.

Subsequently, the unified theory of acceptance and use of technology (UTAUT) is used. This theory of behaviour provides a model to assess the likeliness of success for new technology (i.e. mobility hubs) introduction and understand the drivers of acceptance. By combining the conceptual framework based on the UTAUT with the literature review, an initial causal loop diagram following the system dynamics approach could be constructed. This approach enables mapping and understanding complex and dynamic systems, such as a mobility hub. A qualitative causal loop diagram is constructed that visualises the factors that explain the usage and effects of mobility hubs. However, because this diagram is purely based on literature, the initial causal loop diagram is verified through a round of expert interviews. Together with seven experts, it is checked whether the initial framework based on literature is correct, complete and matches the practice (sub research question 3). Based on their comments, a final version of the causal loop diagram is constructed.

The final step of the research was to execute the actual ex-post evaluation and gathering information to answer the main research question. For this purpose, another round of semi-structured interviews is conducted with six stakeholders (municipalities and mobility hubs and shared mobility providers). In these interviews, the participants are asked to review the performance of their mobility hubs.

Conclusion

Based on theory, through literature study, practice, expert and stakeholder interviews, it seemed that there is not much knowledge on the influencing factors and effects of neighbourhood mobility hubs. Substantial quantitative data lacks, and also qualitatively, the

effects are difficult to identify. Nevertheless, based on the interviewees' perspectives and preliminary researches, it is possible to answer the central research question with the established final causal loop diagram (as displayed in Figure 1). The diagram captures the complex system of factors that influence the usage and effects of shared mobility and mobility hub municipal policy goals of neighbourhood mobility hubs.

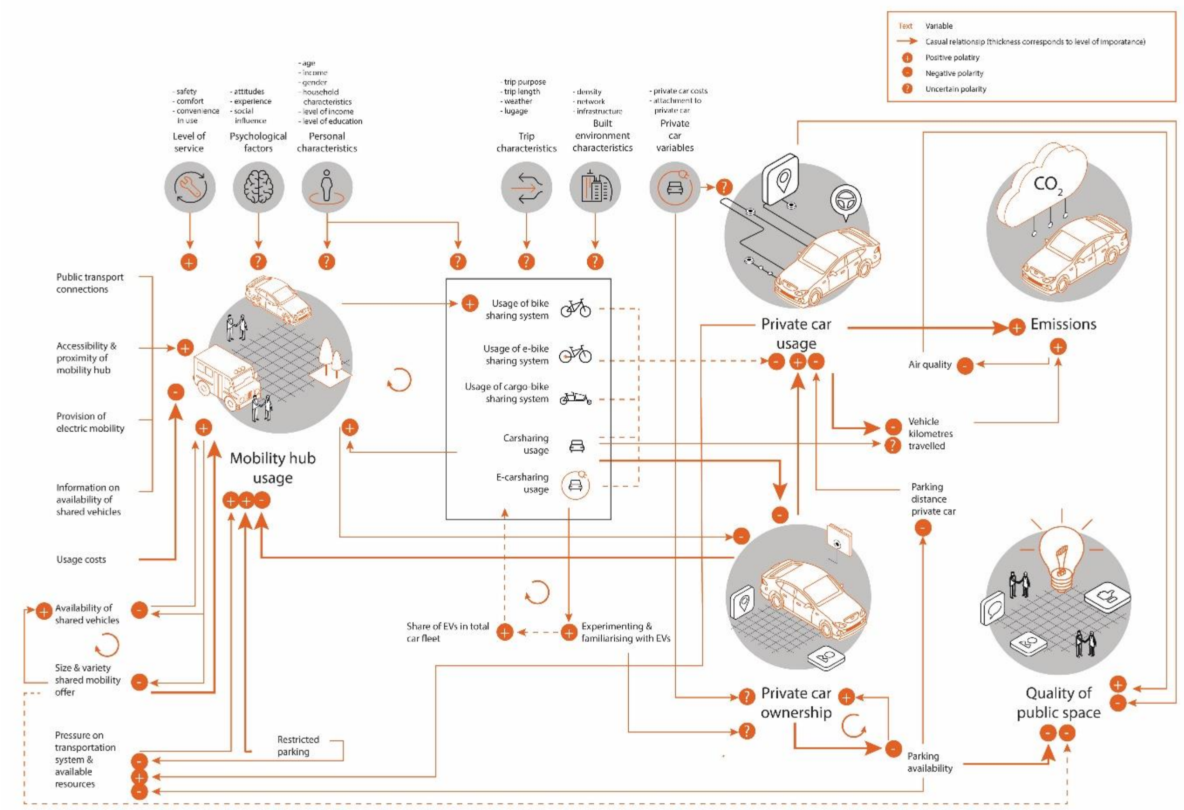


Figure 1: Final causal loop diagram displaying factors that influence the usage and effects of mobility hubs

The core of the diagram can be explained as the following: The location (proximity), attributes, mobility supply, contextual factors (parking policy), and user characteristics and perspective influence the usage of the mobility hub and the mode choice within the hub. Using the mobility hub generally decreases private car usage and ownership, which is again related to reduced emissions, freeing up parking space, and improving public space. Though for some users, this may not be necessarily true as they may not decrease their private car usage and ownership and only increase their mobility and travel more vehicle kilometres due to the mobility hub usage. The main take-aways from the model are thus that there are many factors that could influence the usage of a neighbourhood mobility hub. The diagram shows that mobility hub usage could decrease private car usage and ownership, thus indirectly decreasing emissions and improving public space quality. However, the effects are small and still somewhat uncertain. Similarly, the diagram also demonstrates that neighbourhood mobility usage might not contribute to the policy goals. For example, by providing carsharing services, in total, more car trips might be made.

This research has contributed to filling the research gap of adding scientific knowledge on the topic of neighbourhood mobility hubs, and specifically by doing an ex-post evaluation. It has become clear that it is not yet possible to fully map the mobility hub performance. The interviewees have shared some small promising preliminary insights. Like that, mobility hubs could contribute to municipal policy goals to reduce private car usage and ownership, emissions, and create a liveable city. But as the system is very complicated, and as can be seen in the diagram, the effects are uncertain and might also be negative. All in all, this

research and the established diagram are valuable; they can help future researchers, municipalities, and private parties understand the complex system of mobility hubs.

Recommendations for further research

Future research into neighbourhood mobility hubs is relevant. Repeating this kind of ex-post evaluation, in a few years, is useful for validating the results found in this study. If possible, quantitative data could also be valuable to objectively substantiate the effectiveness of mobility hubs. Additionally, expanding the research scope to other categories of mobility hubs and internationally can lead to more insights. Finally, this research has touched upon the current governance processes of mobility hubs in the Netherlands, but this can be elaborated further in future research.

Recommendations for policymakers

From the policy document analysis, it has become clear that policies for shared mobility can be linked more explicitly to policy goals so that it is clearer what potential shared mobility/mobility hubs have. Moreover, at the moment, shared mobility and mobility hubs are sometimes seen as a(n) (innovation) goal itself instead. The goal is not to innovate, or implement mobility hubs per se, but to ensure liveability and a good mobility system. Mobility hubs are not a goal but can be a means to achieve this. And there also not the sole solution. The coherence between different mobility measures should be more acknowledged. And secondly, in the policy documents a critical reflection on any negative side effects of shared mobility and mobility hub could be added.

Contents

Preface iv
Summary v
Contents ix
List of figures & tables xii
List of abbreviations xv
1. Introduction 1
1.1. Context 1
1.2. Problem definition 2
1.3. Research objective 3
1.4. Research questions 3
1.5. Scope 4
1.6. Relevance 4
1.6.1. Scientific relevance 4
1.6.2. Societal relevance 4
1.7. Thesis structure 5
2. Methodology 7
2.1. Literature study 8
2.2. Qualitative system dynamics 9
2.2.1. Strengths and weaknesses of system dynamics 10
2.2.2. Usage of system dynamics in similar topics 10
2.2.3. Approach 10
2.3. Stakeholder analysis 12
2.4. Semi-structured interviews 12
2.4.1. Strengths and weaknesses of semi-structured interviews 13
2.4.2. Semi-structured interview approach 13
2.4.3. Processing of the interviews 14
3. Mobility hubs – state of the art 16
3.1. Definition and categorisation of mobility hubs 16
3.1.1. Definition of mobility hubs in general 16
3.1.2. Categorisation of mobility hubs 17
3.1.3. Definition of neighbourhood mobility hub 21
3.2. Types of shared mobility 23
3.2.1. Carsharing 23
3.2.2. Bike sharing 24
3.2.3. Scooter sharing 24
3.3. Overview of existing neighbourhood mobility hubs 25
3.3.1. Existing neighbourhood mobility hubs abroad 25
3.3.2. Existing neighbourhood mobility hubs in the Netherlands 26
3.4. Previous research on neighbourhood mobility hubs 28
3.5. Societal goals and ambitions of mobility hubs 29
3.5.1. Sustainable mobility goals in literature 29
3.5.2. Policy documents analysis 31
3.5.3. Discussion policy goals and ambitions 35
3.5.4. Conclusion policy goals and ambitions 35
4. Literature on influencing factors and effects of mobility hubs 38
4.1. Mobility hub literature 38
4.1.1. Influencing factors mobility hub usage 38
4.1.2. Mobility hub effects 41
4.1.3. Conclusion influencing factors and effects mobility hubs 43

4.2. Shared mobility literature 44
4.2.1. Carsharing influencing factors and effects 45
4.2.2. Bike sharing influencing factors and effects 49
4.2.3. Scooter sharing effects 53
4.2.4. MaaS 55
4.2.5. Discussion shared mobility literature 55
4.3. Conclusion influencing factors and effects of mobility hubs 56
5. Causal loop diagram construction 59
5.1. Conceptual framework 59
5.1.1. Unified theory of acceptance and use of technology model 59
5.1.2. Previous applications of the UTAUT model in related research 60
5.1.3. Conceptual framework 61
5.1.4. Model boundaries 62
5.2. Initial causal loop diagram 64
5.2.1. Construction guidelines 64
5.2.2. Explanation of causal loop diagram 64
6. Model validation interviews 68
6.1. Interview set up 68
6.1.1. Expert selection 68
6.1.2. Interview guide 69
6.2. Interview results 70
6.2.1. Benefits and goals of mobility hubs 70
6.2.2. Factors influencing mobility hub usage 70
6.2.3. Effects of mobility hubs 72
6.2.4. Most important variables and correlations 75
6.3. Conclusion interview results 75
6.4. Discussion expert interviews 76
6.4.1. Interview saturation 76
6.4.2. Reflection diagram 77
6.4.3. Reflection experts 77
6.5. Final causal loop diagram 78
6.5.1. Main differences between initial and final CLD 81
6.5.2. Aggregate causal loop diagram 82
7. Ex-post evaluation of mobility hubs 86
7.1. Interview set up 86
7.1.1. Participant selection 86
7.1.2. Interview guide 87
7.2. Interview results 87
7.2.1. Goals 88
7.2.2. Usage 88
7.2.3. Effects on municipal policy goals 91
7.2.4. Governance 92
7.3. Conclusion interview results 94
7.3.1. Usage 95
7.3.2. Effects 95
7.3.3. Governance 95
7.3.4. Reflection on established diagram 96
7.4. Discussion evaluation interviews 96
8. Conclusion, discussion & recommendations 98
8.1. Conclusion research questions 98
8.2. Discussion 102
8.2.1. Contributions of research 102

8.2.2. Reflection of findings 103
8.2.3. Limitations of research 103
8.3. Recommendations 105
8.3.1. Recommendations for further research 105
8.3.1. Recommendations for policymakers 107
Bibliography 109
Appendices: overview 120
A. Scientific paper 121
B. Literature search strategies 131
C. Existing mobility hubs in the Netherlands 132
D. Stakeholder analysis 135
D.1. Stakeholder identification 135
D.2. Interaction of stakeholders 139
D.3. Power-interest grid 140
E. Policy goals analysis 141
F. Interview guide expert interviews 145
G. Interview guide ex-post mobility hub evaluation interviews 147

List of figures & tables

Figure 1: Final causal loop diagram displaying factors that influence the usage and effects of mobility hubs vii
Figure 2: Thesis structure 5
Figure 3: Overview thesis methodology 7
Figure 4: Link research questions and methodology 8
Figure 5: System dynamics process (Slinger & Kwakkel, 2008) 11
Figure 6: Data analysis interviews process 14
Figure 7: Data analysis interviews process 15
Figure 8: Word clouds of goals or services offered (left) and location of mobility hubs (right) based on definitions in Table 1 17
Figure 9: Geographical city zones (APPM & Goudappel, 2020) 18
Figure 10: Categorisation of hubs based on scale. Based on (APPM & Goudappel, 2020) .. 19
Figure 11: Impression of neighbourhood mobility hub (Mobipunt, n.d.-c) 22
Figure 12: Shared mobility and its modalities (Ferrero et al., 2018; Machado et al., 2018; Münzel et al., 2020; Roukouni & Correia, 2020; Shaheen et al., 2020) 23
Figure 13: Bike sharing typology (van Waes et al., 2018) 24
Figure 14: Electric scooter (van de Laak, 2020) 25
Figure 15: Electric moped (Thies, 2020) 25
Figure 16: 3-stage urban transport policy development process (Teoh et al., 2020) 30
Figure 17: Shared mobility policy goals statements and the number of times mentioned in policy documents, sorted by categories. Statements including sources are represented in Table 29 (Appendix E) 33
Figure 18: Mobility hub policy goals statements and the number of times mentioned in policy documents, sorted by categories. Statements including sources are represented in Table 30 (Appendix E). 34
Figure 19: Ranked importance (very or rather important) of mobility station components (Heller, 2016) 39
Figure 20: Mode of transport used instead of carsharing/bike sharing in Offenburg mobility stations (Heller, 2016). Note: multiple responses possible: sum of responses >100% 42
Figure 21: Research areas of impacts of shared mobility (Roukouni & Correia, 2020). The focus of research is on orange areas. 45
Figure 22: Transport mode used if HTM-fiets was unavailable (Van Marsbergen, 2020) 51
Figure 23: Structure and methodology of the chapter 59
Figure 24: UTAUT2 model (Venkatesh et al., 2012) 60
Figure 25: UTAUT2 model applied to shared mobility and mobility hubs 62
Figure 26: Bull's eye diagram 63
Figure 27: Initial causal loop diagram of neighbourhood mobility hub usage and effects factors 66
Figure 28: Saturation graph of interviews 77
Figure 29: Diagram cut out of influencing factors mobility hub usage 79
Figure 30: Diagram cut out of shared modalities 80
Figure 31: Diagram cut out of e-carsharing feedback loop 80
Figure 32: Legend of final causal loop diagram 81
Figure 33: Diagram cut out of variable categories 81
Figure 34: Final complete causal loop diagram of neighbourhood mobility hub usage and effects factors 83
Figure 35: Final aggregate causal loop diagram of neighbourhood mobility hub usage and effect factors 84

Figure 36: Number of trips with Cargoroo cargo-bikes per eHUB location from opening in June 2020 to December 2020 (College van B&W Nijmegen, 2021a). *Cargo-bike at UMC in September moved to Hengstdal 90
Figure 37: Number of trips with Amber cars per eHUB location from June 2020 to March 2021 (College van B&W Nijmegen, 2021a) 90
Figure 38: Total number of trips with Amber cars from June 2020 to March 2021 (College van B&W Nijmegen, 2021a) 90
Figure 39: Copy of Figure 34 Final causal loop diagram of neighbourhood mobility hub usage and effects factors...... 101
Figure 40: Causal loop diagram mobility hub usage and effects 128
Figure 41: Stakeholder interaction......140
Figure 42: Power-interest grid......140

Table 1: Search keys used in the literature study 9
Table 2: Mobility hub definitions...... 16
Table 3: Mobility hub amenities. Based on (APPM & Goudappel, 2020; SEStran, 2020; Urban Design Studio, 2017; Zwikker et al., 2021) 20
Table 4: Overview of foreign cities with active neighbourhood mobility hubs 26
Table 5: Overview of (number of) public mobility hubs in the Netherlands (July 2021) (Amber, n.d.; eHUB Arnhem, n.d.; eHUB Nijmegen, n.d.; Hely, n.d.-c; Juuve, n.d.; MOBIAN, n.d.; Mobipunt, n.d.-b; reisviahub, n.d.) 26
Table 6: Municipal documents for policy goals analysis 31
Table 7: Summary of mobility hub factors and effects with positive or negative impacts. (For legend see p.48) 44
Table 8: Summary of carsharing factors and effects with positive or negative impacts. (For legend see p.48) 48
Table 9: Summary of bike sharing factors and effects with positive or negative impacts. (For legend see p.48) 52
Table 10: Summary of e-bike sharing factors and effects with positive or negative impacts. (For legend see p.48)......53
Table 11: Summary of cargo-bike sharing factors and effects with positive or negative impacts. (For legend see p.48)......53
Table 12: Summary of scooter sharing factors and effects with positive or negative impacts. (For legend see p.48)......55
Table 13: Translation policy goals to variables in CLD 65
Table 14: Participants of expert interviews......69
Table 15: Phases and objective per phase of expert interviews......69
Table 16: Opinions from interviewees on mobility hub usage in initial CLD (Figure 27 on page 66). Comments in orange are adjusted in final CLD. 71
Table 17: Opinions from interviewees on mobility hub effect in initial CLD (Figure 27 on page 66). Comments in orange are adjusted in final CLD. 73
Table 18: Participants of mobility hub evaluation interviews......87
Table 19: Phases and objective per phase of expert interviews......87
Table 20: Advantages and disadvantages of governance approaches for mobility hub implementation......96
Table 21: Overview of most crucial variables (in random order) and correlations mobility hub usage and effects. Text in orange are the policy goals......99
Table 22: Mobility hub factors and effects with expected impacts. Impact relates positive/negative impact of the factor on the effect. 128

Table 23: Search keys and number of results 131
Table 24: eHUBS in Arnhem and Nijmegen (eHUB Arnhem, n.d.; eHUB Nijmegen, n.d.) .. 132
Table 25: Mobipunts (Mobipunt, n.d.-b) 132
Table 26: Hely hubs (Hely, n.d.-c, n.d.-b, n.d.-d) 133
Table 27: Juuve hubs (Juuve, n.d.) 133
Table 28: Current mobility hub and shared mobility providers in the Netherlands 138
Table 29: Identified policy goals for shared mobility 141
Table 30: Identified policy goals for mobility hubs 142
Table 31: Shared mobility policy goals categorised. Statements including sources are represented in Table 29 (Appendix E). Number between brackets is number of times this statement is reported in the documents. (Note: Original text in Dutch, translated to English) 144
Table 32: Mobility hub policy goals categorised. Statements including sources are represented in Table 30 Appendix E. Number between brackets is number of times this statement is reported in the documents. (Note: Original text in Dutch, translated to English) 144

List of abbreviations

B2B	Business-to-Business
B2C	Business-to-customer
CLD	Causal loop diagram
e-cargo bike	Electric cargo bike, Dutch: elektrische bakfiets
e-moped	Electric moped, Dutch: elektrische scooter/e-scooter
e-scooter	Electric scooter, Dutch: elektrische step/e-step
GHG	Greenhouse gas
MaaS	Mobility-as-a-Service
P2P	Peer-to-Peer
PT	Public transport
PVS	Personal vehicle sharing
SD	System dynamics
SUMP	Sustainable urban mobility plan
UTAUT	Unified theory of acceptance and use of technology
VKT	Vehicle kilometres travelled

Introduction

1. Introduction

This introductory chapter of the thesis aims at presenting the context and relevance of the study, the research objective, and questions.

1.1. Context

The overall world's population is increasing at a fast rate. Even more significantly than the population growth is the number of people residing in urban areas. In 2019, 55% of the world's population resided in urban areas, and the UN has even predicted that this number will increase up to 68% in 2050 (UN, 2019). Similarly, the European Commission has stated that in some European countries, the urbanisation rate could rise to over 90% (European Commission, 2017). More people residing in urban areas bring more economic activities such as workplaces, cultural activities, schools, etc. The urbanisation trend, together with extensive economic activities in these urban areas, has led to multiple problems. In the field of transport, for example, congestion, air pollution, safety, and noise pollution.

Besides, there is also the emerging reality of climate change and, in terms of transport, awareness that more sustainable forms of travel are becoming necessary. Currently, urban mobility accounts for 40% of all CO_2 emissions of road transport (European Commission, 2017). With the Paris Agreement EU target of 60% reduction in greenhouse gas emissions by 2050, the transportation sector and urban areas will play an essential role in achieving this target (Gota et al., 2019). Cities will need to accommodate the growing urban population while satisfying the mobility needs of these people and taking a sustainable approach to work on the current problems. In this context, the EU has promoted the concept of sustainable urban mobility plans (SUMPs) (Kiba-Janiak & Witkowski, 2019). These SUMPs are long-term plans designed to balance passenger and freight transport demands and citizens' quality of life (Wefering et al., 2014). The research of Banister (2008) categorises sustainable mobility approaches into four approaches:

1. Reducing the need to travel (substitution)
2. Transport policy measures (modal shift)
3. Land-use policy measures (distance reduction)
4. Technological innovation (efficiency increase)

Cities are taking several actions in line with these four policy goals. One of these measures is, for example, aimed at reducing car use and ownership in urban areas. Fossil fuelled cars are not only an environmental burden, but they also require a lot of (public) space. Therefore, urban municipalities apply parking policies to such as a low(er) parking standards (Mingardo et al., 2015). One of the ways to support this policy and actually reduce the demand for parking is the transition from a mobility system based on owning to sharing.

Shared mobility is the short-term use of a shared transportation service on an 'as-needed' basis (Machado et al., 2018; Shaheen et al., 2017). In general, theory shows that due to higher occupancy rates of vehicles, shared mobility has the potential to reduce traffic congestion and the need for parking spaces and could decrease the total number of vehicles (Machado et al., 2018; Nijland & van Meerkerk, 2017).

When several shared modalities are combined, the term 'mobility hubs' comes up. Mobility hubs, or in this context also called multimodal hubs, are defined as places where public transport modes come together and that allows travellers to travel easily and flexibly, using various, (clean) transport modes to suit their specific journey. This could range from a station area including access/egress facilities to a small-scale hub with a few shared vehicles offered.

Though this applies to a broad international context, the potential of shared mobility is also acknowledged in the Netherlands as, for example, follows from the Dutch mobility policy plan 'Deltaplan 2030' (Mobiliteitsalliantie, 2019). In relation to shared mobility, the Deltaplan 2030 also uses the term 'mobility hub'. Similarly, Natuur & Milieu (2020) states that a transition in the mobility system is required that makes sustainable forms of mobility attractive and offer less space for the car. They believe that mobility hubs are an important part of this new mobility system. In other words, "[mobility hubs] have the potential to become a catalyst in regions aimed at protecting the environment and promoting sustainable transportation choices and organise low-emission transport options" (Storme et al., 2021, p. 5).

1.2. Problem definition

Based on initial research, it seems that scientific literature regarding mobility hubs (on a local level) is scarce. This is supported by the (limited) existing studies on the topic (Aono, 2019; Bell, 2019; Miramontes, 2018; Tippabhatla, 2020). Tippabhatla even states that the key problem when researching mobility hubs is the fact that they are either future-oriented or pilot studies with minimal infrastructure. Besides, "literature on most of these mobility hubs cannot be considered as scientifically significant as most of them are proposals by the respective jurisdictions" he argues (Tippabhatla, 2020, p. 8). This leads to the gap for this thesis which is subdivided into three themes.

Lack of scientific research regarding the concept of (neighbourhood) mobility hub

Although research is done on different concepts of shared mobility separately, such as the effects of bike and carsharing, there is limited research on when these mobility options are physically integrated into mobility hubs. Besides, published research focuses on medium to large mobility hubs, such as transferia at the edge of cities, Park + Ride, Bike + Ride facilities at stations. On a smaller scale, the relatively newer form of mobility hubs, the neighbourhood mobility hub, is left rather untouched, at least in the scientific literature. Tough, scientific published papers are lacking (see Appendix B), the research on this topic is expanding through several recent theses and other (consultancy) research projects. While the attention for neighbourhood mobility hubs is rising, a fixed (scientific) definition is missing. Hence, this research uses the following preliminary definition:

A neighbourhood mobility hub is a physical location with a catchment area of approximately 500 meters radius, where a variety of shared mobility services are offered. Of which at least one shared car and one shared (e-)bike.

Current researches are predominantly ex-ante studies of mobility hubs

The (limited) currently available literature and other studies on neighbourhood mobility hubs are predominantly ex-ante studies, focussing on the potential of the neighbourhood mobility hubs. Albeit already several hubs have opened in the Netherlands, as well as in other European cities (see section 3.3.1), there lacks a scientific evaluation of these hubs.
Nevertheless, Knippenberg (2019) and Van Rooij (2020) have both conducted a user survey and analysis of existing hubs. However, they also indicated that they still recommend doing more research into the actual effects after the implementation of a mobility hub, as their obtained sample size is limited and statistical power of the research is lacking. Moreover, their research does not include an overall evaluation of the mobility hub's effects or assessment of satisfaction of the beforehand defined (policy) goals. An ex-post evaluation is

very valuable in testing whether the perceived potential effects indeed actually occur. Moreover, the evaluation is not only a contribution to scientific knowledge but also for parties considering implementing a mobility hub.

Need for more research on implementation strategies
Governance and government policies are key elements for the development and support of shared mobility and technology development (Banister, 2008; Hull, 2008; Meng et al., 2020). As Miramontes (2018) states in the recommendation chapter of her doctoral thesis, there is still potential to carry out a process evaluation to identify success factors and barriers to the planning, implementation. Aono (2019) supports this, who states that further research on implementation strategies and objectives of mobility hubs is essential. Besides, also in practice, municipalities are expressing their ambition for more shared mobility (and the creation of mobility hubs), but they are struggling with the question of how they are going to achieve this, what role they have and how to collaborate with private parties (Roukouni & Correia, 2020).

To conclude, the identified knowledge gap is that a neighbourhood mobility hub concept is relatively new, and scientific literature on the topic is scarce. The limited research done are predominantly ex-ante studies that explored the potential of a mobility hub. Yet, no ex-post evaluation has been conducted on the actual effects. To evaluate the effectiveness and make recommendations on how to improve the effectiveness in the future, it is important to understand the factors that contribute to, or withhold, these (positive) effects. Moreover, next to the effects of mobility hubs, also the implementation strategies need to be further investigated. As scholars have suggested, governance and government policies are key elements in the effectiveness of shared mobility, thus also mobility hubs.

1.3. Research objective

The previous sections show that next to societal interest in mobility hubs, also scientifically, the opportunities and effectiveness of mobility hubs are not fully documented. This leads to the following main objective of this study: to deliver knowledge on the factors that influence the effects, with respect to their policy goals, of neighbourhood mobility hubs. This is done through an ex-post evaluation of already existing neighbourhood mobility hubs in the Netherlands. Based on this evaluation, recommendations can be made on how (future) mobility hubs can be realised so that they deliver a significant contribution to the municipal policy goals.

The research objective is split into two main parts. First, this thesis identifies the (potential) effects and influencing factors of a mobility hub's contribution to policy goals. These factors, originating from literature, are summarised in a causal loop diagram. This diagram is verified to the practice by conducting several interviews with mobility experts. The second part of the research is to perform empirical research through interviews with stakeholders to evaluate existing mobility hubs. In these meetings, the theoretical findings are compared to practice, and the established model is used as a basis for evaluation. It can help to indicate the reasons for the mobility hub perceived effectiveness and eventually deliver recommendations for stakeholders on how to develop a successful mobility hub.

1.4. Research questions

In short, the knowledge gap and objective of this study can be translated into the following main research question:

Which factors have influenced the usage and the effects, regarding shared mobility and mobility hub municipal policy goals, of existing neighbourhood mobility hubs?

To be able to answer the main research question, several sub-research questions are composed. The sub-research questions are as follows:

1. What are the municipal policy goals for shared mobility and mobility hubs, and how can a mobility hub be assessed?
2. What are the factors explaining the usage and effects of neighbourhood mobility hubs in literature?
3. To what extent does practice confirm the usage factors and effects, of neighbourhood mobility hubs, obtained from literature research?

1.5. Scope

This research focuses on Dutch mobility hubs at a local level, also called 'neighbourhood mobility hubs'. These hubs are primarily characterised by their provision of a variety of shared mobility services, such as shared cars, shared mopeds, shared (e-)bicycles and cargo bicycles. For a more detailed description of neighbourhood mobility hubs, see section 3.1.3 and Figure 11. The research is conducted in the Netherlands, which means that mobility hubs' usage factors and effects are focused on the Dutch situation.

The term 'effects' of the mobility hubs refers to their contribution to the policy goals that led to the realisation of the mobility hub. The focus hereby is on the municipal policy goals, as neighbourhood mobility hubs are looked at, which means that the primarily involved public authority is the local municipality.

1.6. Relevance

The relevance of this thesis is both on a scientific and societal level. In this section, the scientific and societal relevance will be discussed.

1.6.1. Scientific relevance

Mobility hubs are an emerging concept in the field of mobility, and beneficial effects are expected to society. However, scientific background knowledge on the neighbourhood mobility hub is missing (see section 1.2). This master thesis will provide new scientific insights on neighbourhood mobility hubs, and secondly, the evaluation of currently existing (Dutch) neighbourhood mobility hubs regarding their effects. This is done through a scientific approach based on literature and qualitative research on the factors contributing to a successful mobility hub from a stakeholder perspective.

1.6.2. Societal relevance

The previous sections and the literature study show that urban areas are facing huge challenges. The developments as climate change, population growth and urbanisation together cause transport and mobility problems such as high CO_2 emissions, traffic safety, congestion, reduced accessibility, and limited space. Urban areas are challenged to improve this and create liveable cities to accommodate the increasing population density (Nabielek et al., 2016). Innovative and rapid developments in technology and other fields, on the other hand, provide opportunities to create cleaner and smarter cities. Shared mobility and mobility hubs are one of the promising concepts for a sustainable mobility system and are therefore increasingly incorporated as measures of policy goals. However, public as well as private parties are still uncertain about the effects of mobility hubs and whether and to what extent they contribute to certain policy goals. Besides, policy makers are also struggling with what role to take and how to implement successful hubs according to their, in advance, set policy goals. This research could therefore provide recommendations on a successful realisation of mobility hubs.

1.7. Thesis structure

In this first chapter, the problem, objective, and relevance for this research were identified, and research questions were formulated. Chapter 2 discusses the methodology for this research. Subsequently, the state of the art of mobility hubs is outlined (Chapter 3). This is done in several sections that elaborate on the definition and categorisation of a mobility hub, identification of existing neighbourhood mobility hubs, and finally, a review of the common policy goals and ambitions of a mobility hub. The following chapter (Chapter 4) provides a review of literature on influencing factors and effects of mobility hubs and shared mobility. The knowledge gained by these literature reviews are used to establish an initial causal loop diagram which is presented in chapter 5. This model is then validated through expert interviews, which chapter 6 elaborates on. The final model is used for the evaluation of some currently existing mobility hubs in the Netherlands. This ex-post evaluation of mobility hubs is presented in chapter 7. Chapter 8 then concludes and discusses the insights on this research, followed by recommendations.

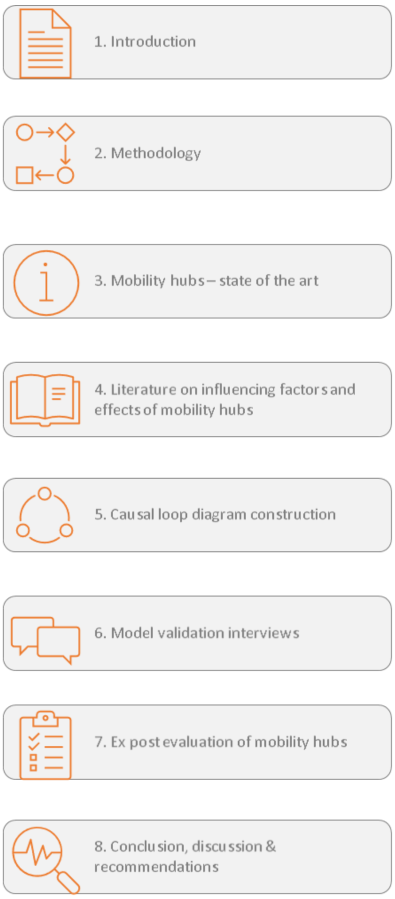
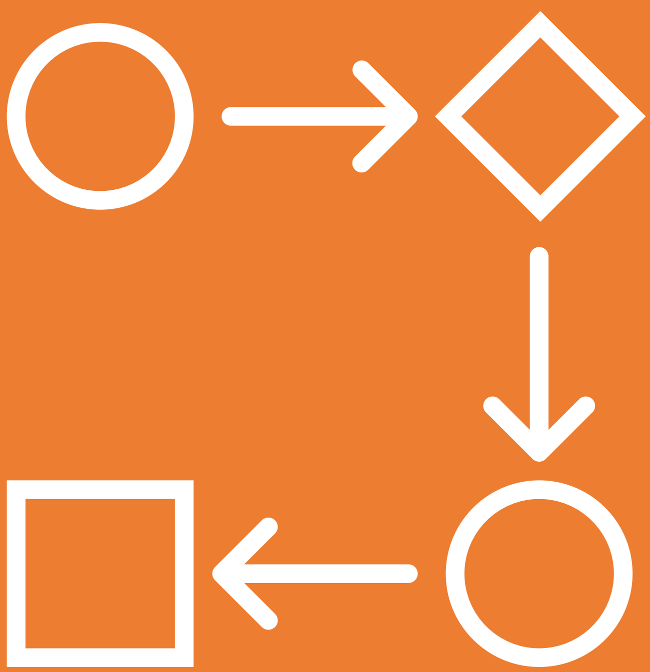


Figure 2: Thesis structure



Methodology

2. Methodology

In this chapter, the methodology of the research is discussed. To answer the research questions, a research approach and methodology has to be defined. The chapter is split up into four subsections that discuss different methodologies or research steps (dark grey boxes in Figure 3). But first, the type of research and research design are discussed.

Qualitative research approach

As most mobility hubs are only recently in operation (the majority of the hubs opened since summer 2020), it is challenging to evaluate the effects of those hubs. At least in a quantitative way, because not much quantitative data is available yet, and if available, it may not be very reliable. Moreover, the recent COVID-19 pandemic has a significant impact on mobility. Next to the fact that, because of government-imposed travel restrictions, the overall human mobility has decreased, as well as the usage of shared mobility modes (Bucsky, 2020; Shokouhyar et al., 2021). Thirdly, through an initial inventarisation with shared mobility providers, they did not seem willing to share their quantitative data. Therefore, it is concluded that quantitative research on this topic is not feasible and scientifically sound, and the decision is made to conduct this research qualitatively. The research thus focuses on the evaluation of mobility hubs through interviews rather than quantitative data.

This qualitative approach fits the objective of the research as to evaluate the effects of mobility hubs with respect to their set goals or expectations in advance. Because qualitative studies can be used to explore and develop hypotheses that can be tested in a quantitative analysis (Zarabi et al., 2019). Or in other words, qualitative research fits the aim of finding the "why" and "how" of a new phenomenon (Moradi & Vagnoni, 2018). Furthermore, qualitative methods have the advantage that the data is collected with greater efficiency and reduced risk of misunderstanding or self-presentation biases compared to some quantitative methods (Yilmaz, 2013). Moreover, due to the societal developments around mobility hubs and the required collaboration between stakeholders, such as public authorities, shared mobility providers, and users, a qualitative approach to map different perspectives suits this research well.

Research design

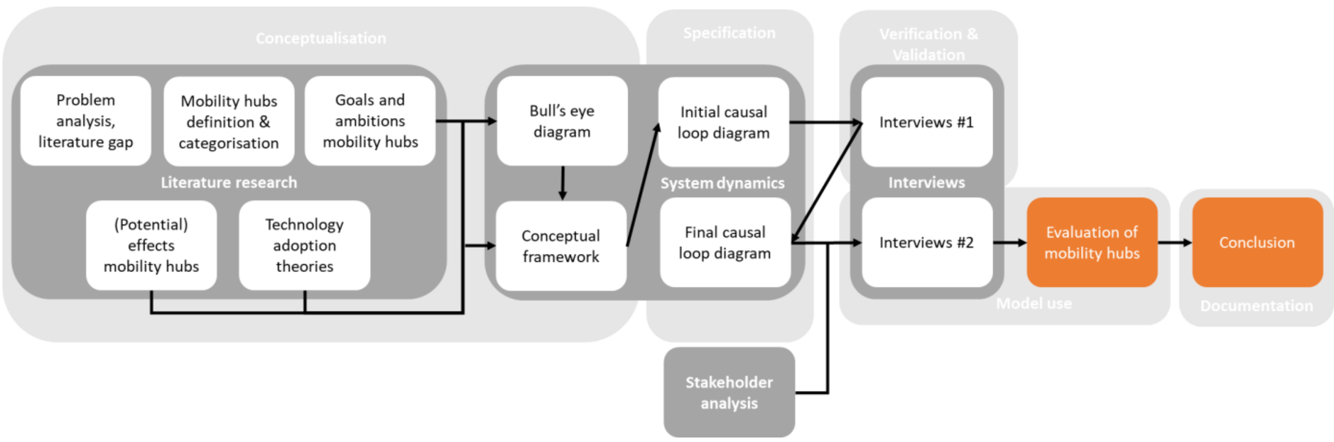


Figure 3: Overview thesis methodology

The research is set up in different steps. It starts with an in-depth understanding of the problem and some related required information. Secondly, based on literature and theories, an initial causal loop diagram is established. Then, interviews are conducted to verify and validate the model and compare it to their observations from practice. This leads to a final causal loop diagram which forms the basis for the second round of interviews with stakeholders on how they evaluate the existing mobility hubs. This process is visualised in Figure 3, and the link between the methods and research questions are displayed in Figure 4.

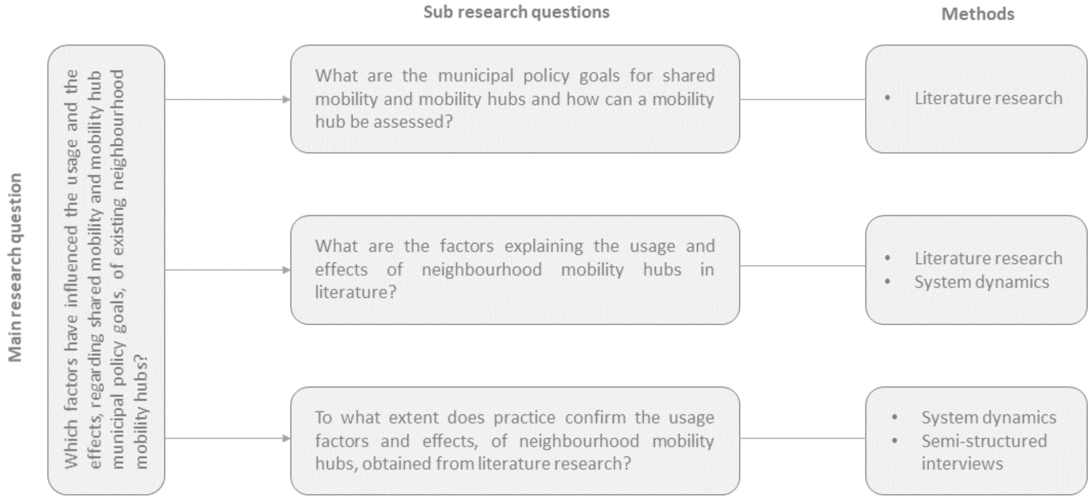


Figure 4: Link research questions and methodology

2.1. Literature study

The literature study is performed for an up-to-date overview of the literature in the field of mobility hubs. The main research topics for the literature study are to:

- Identify the problem and literature gap
- Define a methodology for research
- Define and categorise mobility hubs
- Define effectiveness and successfulness of a mobility hub, policy goals (sub-research question 1)
- Employ a literature review on influencing factors and effects of mobility hubs and shared mobility (sub-research question 2)
- Develop a causal loop diagram based on influencing factors and effects of mobility hubs and shared mobility

A literature search is performed, with the search keys as in Table 1, by screening and selecting relevant studies (for journals, conference papers, reports and theses) from different search engines: Scopus, Science Direct, and Google Scholar. The usefulness of the search results is assessed based on the title, year of publication, number of citations and the publisher. Then the abstract is scanned. When an interesting article is found, the references are also examined and by whom the article is cited, so-called 'snowballing'.

Next to scientific literature, also grey literature like reports, mobility consultants and government agencies are used. These publications are used for the mobility hub definition and categorisation and for the identification of mobility hub policy goals. Relevant documents are publications that contain a vision, ambition and or requirements for a mobility hub. These documents are found by using the Google search engine.

Table 1: Search keys used in the literature study

Field	Search keys
Problem definition and literature gap	"mobility hub", "neighbourhood mobility hub", neighbourhood AND mobility AND hub, "mobility hub" AND shared AND mobility, ("multimodal" OR "multi-modal") AND transport* AND hub
Methodology	System dynamics approach, "causal loop diagram" construction, semi-structured interviews, qualitative interview coding,
Mobility hub definition	"mobility hub" AND definition
Mobility hub policy goals[1]	"mobility hub" AND policy, "shared mobility" AND policy, shared mobility policy goals, "sustainable urban mobility plan", SUMP AND shared mobility
Influencing factors and effects of shared mobility and mobility hubs	shared mobility impacts, ("carsharing" OR "car sharing") effect, ("bike sharing" OR "bike-sharing") system impact, ("micromobility" OR "micro-mobility") effect, "mobility hub" AND effects, shared mobility literature review, mobility as a service literature review, shared mobility car ownership, shared mobility car usage, shared mobility emissions
Causal loop diagram construction	"system dynamics" AND "shared mobility", technology adaptation "shared mobility", "causal loop diagram" construction

2.2. Qualitative system dynamics

A system dynamics approach is used to map the factors explaining the usage and effectiveness of the mobility hub to set up a causal loop diagram that visualises these factors and the relationships between them. The causal loop diagram and system dynamics background enable visualising the obtained factors from literature in a structured manner by following the causal loop diagram design principles. The remainder of this section further explains the system dynamics methodology, the strengths and weaknesses, usage in similar topics and finally, the approach with respect to this thesis.

The system dynamics (SD) method is a widely recognised method that is developed in 1961 by Forrester to study, design and manage complex feedback systems by modelling their macroscopic structure (Papanikolaou, 2011). It has proved to be a valid method with several opportunities for applications in economic, organisational, and business systems. With a system dynamics methodology, the complex system can be analysed from a qualitative and quantitative point of view (Vecchio et al., 2019). The qualitative aspect is analysed through a causal loop diagram (CLD), and the quantitative behaviour can be simulated through hydraulic compartment models in a top-down manner (Papanikolaou, 2011). These CLDs are mainly used prior to a simulation analysis to very clearly illustrate basic components with internal relations and external interdependencies (Binder et al., 2004; Pruyt, 2013). The possible behaviour of the system is shown through the variables, their causal links and feedback loops.

The qualitative part of system dynamics methodology is used in this research for developing a causal loop diagram because it offers a recognised standard and structure to show the dynamics and complexity of the mobility hub system on a high abstraction level. As covered in the introduction chapter, several developments in society accentuate the need for changes in the current transport and mobility pattern. This issue is very complex due to dynamics and several fast developments (technological, COVID-19 pandemic). This reality makes for a challenging answer to the thesis objective. Besides, practically, as there is limited knowledge on mobility hubs, a narrow approach would only partially answer the research

[1] For this topic also a lot of grey literature is used (see section 3.5.2)

question. In brief, the system dynamics approach is a tool to provide insight into complex issues. As the research objective of the thesis is broad and complex, only this tool is suitable to offer a comprehensive overview of the existing mechanisms. Moreover, another motivation lies in the fact that system dynamics and causal loop diagram have been proven useful in related research, as described in the paragraphs below.

A causal loop diagram consists of four basic elements: variables, links, link signs and loop signs. A variable is something that can change over time. Variables are connected via links, arrows. Variables can have a positive reaction, meaning that variable A moves in the same direction as variable B, or variables can change in opposite (negative) directions. Signs near the arrows indicate whether the causal influence is positive (+) or negative (-). Some variables and links together can create a feedback loop. There are two types of causal loops: reinforcing (R) and balancing (B) loops. A reinforcing loop indicates that a change in one direction leads to more change in the same direction. In a balancing loop, a change in one direction is countered by a change in the opposite direction (Sterman, 2000).

2.2.1. Strengths and weaknesses of system dynamics

Papanikolaou (2011) mentions that the strengths of system dynamics are its high abstraction, educational clarity and computational robustness. Pruyt (2013) presents several arguments in favour of qualitative SD, namely that it is useful for describing a problem situation, causes, solutions and potential risks. Moreover, it is a method that enables people to externalise and share their mental models and assumptions. To summarise, he states that SD can be seen as a problem structuring and discovery tool through the features of an SD model such as the understanding of feedback loops, and revelation of the bigger picture, risks, opportunities, hypotheses, policy variables and structures.

Though CLDs are interesting diagrams to summarise and communicate, Pruyt (2013) mentions that one should be very careful when communicating CLDs as people that are not familiar with CLDs, may not be able to understand and appreciate the diagram. This is something to consider during the interviews when this model will be discussed.

2.2.2. Usage of system dynamics in similar topics

The system dynamics approach can be applied to various research fields, with transportation being one of them. Abbas & Bell (1994) suggested that because transportation systems are complex and involve different stakeholders, system dynamics models can provide a convenient overview of the entire system and enable the functional presentation of the transport planning process to policymakers. In addition, Vecchio et al. (2019) describe that due to the complexity of characterising mobility as a process, SD is a useful approach addressing this complexity and characterising issues related to smart mobility. Though Vecchio et al. (2019) state that the application of SD in people's mobility is under-researched, this type of application is not completely absent. Shams Esfandabadi et al. (2020) follow a system thinking approach to develop a conceptual framework to analyse the environmental effects of carsharing services. The outcomes of an extensive literature review are used to build a causal loop diagram to clarify interconnections among the identified variables to eventually present the environmental effects of carsharing. To arrive at this CLD, forty papers are considered that apply SD modelling (and the construction of a CLD) for a transport-related problem considering the environmental impacts of which only a few into shared mobility.

2.2.3. Approach

Figure 5 shows a convergent and divergent process of the development of a system dynamics model. For the model construction itself, the process can be divided into three main phases (Pruyt, 2013; Slinger & Kwakkel, 2008). After these three steps, the 'model use' and 'documentation' phases follow, which are meant to answer the research questions based on the model eventually. This process and its steps are also shown in Figure 3 (light grey boxes) and Figure 5:

- Problem description and conceptualisation phase:
  1. Problem analysis
  2. Formulation of causal theory
  3. Identification of model boundaries and most important variables: Bull's eye diagram
- Specification phase: developing of (initial) causal loop diagram
- Verification & Validation: interviews round 1 (see section 2.4)
- Model use: interviews round 2 (see section 2.4)
- Documentation: writing conclusions and recommendations in chapter 8

The problem description and conceptualisation phase can be further split into four steps. The first step is to extract from literature the most relevant relations, with respect to the (potential) effects and influencing factors of a mobility hub's contribution, to policy goals. This problem analysis is required to gather knowledge and structure the problem. Next, several theories and models are identified that will form the basis of the model. The third step is to illustrate the boundaries of the system; the variables are therefore placed in a Bull's eye diagram. Finally, the conceptualisation phase is ended with input for the next phase, the specification, in which a CLD will be set up.

When an initial CLD is developed, a verification and validation round will follow through semi-structured expert interviews (see section 2.4). This might lead to some alterations and the development of a final CLD that will answer the research questions. The second round of interviews aims to gather stakeholder's perceptions on the effects of the active mobility hubs based on the CLD (see section 2.4). This is the model use phase. Based on the findings from these interviews, this thesis's final conclusions, discussion, and recommendations are written, the so-called documentation phase.

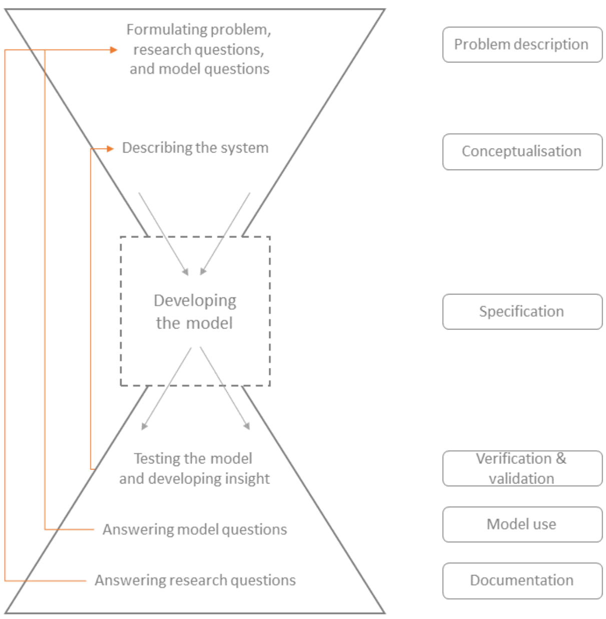


Figure 5: System dynamics process (Slinger & Kwakkel, 2008)

2.3. Stakeholder analysis

The planning, implementation and operation of a mobility hub require different actors to collaborate. As beforementioned, these processes are a key element in the development of mobility hubs. The aim of performing a stakeholder analysis is twofold. First, as the definition and objectives of a mobility hub can differ per actor (Kwantes et al., 2019), it is interesting to investigate the actors involved and compare their aims. Secondly, for this thesis research, a stakeholder analysis is required before conducting the interviews (on the ex-post evaluation of mobility hubs) to determine the relevant actors to interview and to know their interdependencies.

A stakeholder analysis is an important tool to get insight into the involved actors, their intentions, interrelations and interests (Bryson, 2004; Varvasovszky & Brugha, 2000). As Spickermann et al. (2014) mention, mobility systems are complex situations and constitute of multiple relationships, which means that a large variety of stakeholders, with varying interests, are involved in the planning process.

Bryson (2004) describes various stakeholder identification and analysis techniques. Because this analysis aims to get insight into the stakeholders and to identify which stakeholders are relevant to further interview, the basis stakeholder analysis technique is used. This technique offers a quick and useful way of identifying stakeholders and their interests, views, key strategic issues and to start the process of identifying coalitions of support and opposition (Bryson, 2004).

When the stakeholders are identified, a power versus interest grid is set up. The horizontal axis displays the power of the stakeholders, and the vertical axis represents the interest of an actor in the strategic activity. This approach categorises the stakeholders into four groups: subjects, players, crowd and context setters (Eden & Ackermann, 1998). Based on this grid, insight is gained which stakeholders' power and interest, and therefore which stakeholder groups are interesting to interview.

2.4. Semi-structured interviews

Because of few literature and data on this novel research topic and the qualitative approach of the research, there are two rounds of semi-structured interviews conducted with two different objectives:

- 1st round of interviews is to verify and validate the initial causal loop diagram. Together with experts, it is checked whether the initial framework based on literature is correct and complete and matches the practice
- 2nd round of interviews is to gather stakeholder's perceptions on the effects of the existing mobility hubs of which they are/were involved and evaluate these effects based on the established model

In the scientific literature, a research interview is categorised by a two-person conversation initiated by the interviewer and is to obtain research-relevant information specified by the research objective (Adhabi & Anozie, 2017; Luo & Wildemurth, 2016). The literature substantiates the choice for semi-structured interviews for qualitative research, as is required to answer this thesis's central research question. Conducting interviews is one of the most common methods in qualitative research (Kallio et al., 2016). There are three types of research interviews: structured, semi-structured and unstructured. Structured interviews have a fixed questionnaire with closed-ended questions, thus commonly used in survey research. Unstructured interviews are not based on any prepared set of questions at all. In between these two approaches is the semi-structured interviews. The semi-structured interview involves prepared questioning and evoking elaborates responses, and leaving room for improvised questions. Semi-structured interviews are a popular data collection method due to their versatility and flexibility (Kallio et al., 2016).

2.4.1. Strengths and weaknesses of semi-structured interviews

The method of semi-structured interviews has, just like any other method, its pros and cons. One of the greatest advantages of semi-structured interviews is the flexibility of this approach. First, several key questions are discussed, followed by the possibility to elaborate on information that is important to the interviewee but has not necessarily been thought of beforehand by the researcher (Gill et al., 2008). Besides, semi-structured interviews enable and stimulate the reciprocity between the participant and interviewer (Galletta, 2013).

On the other hand, analysing and generalising responses with this kind of interview is time-consuming and challenging. Furthermore, as stated by (Luo & Wildemurth, 2016), the interview guide needs to be carefully planned and pretested for the most useful results. This poses the risk of the interview becoming too structured, though, which is also not desired as it limits the possibilities for open responses. A good balance needs to be found.

The motivation for using semi-structured interviews in this research cannot be described better than, as is stated by Wilson (2014), semi-structured interviews are especially helpful in gathering data about complex issues and when clarification of the answers is desired. And that is the case in this research.

2.4.2. Semi-structured interview approach

The research approach for the interviews in this study consists of the following steps and are based on (Kallio et al., 2016; Wilson, 2014):

1. Determination of goal of interviews
2. Develop interview guide
3. Recruit interviewees
4. Pilot test interview
5. Interview execution
6. Approval of interview transcripts
7. Interview reporting

The objective of the interviews varies in the two interview rounds (see bullet points above). The first round is used to verify the initial causal loop diagram and determine whether it correctly visualises the influencing factors and their interrelations or needs some adjustments and expansions to match the practice better. The second round of interviews focuses on reflecting on the effects of the existing mobility hubs and trying to link the observations to the framework. The exact goal or interview guide can vary according to the type of stakeholder interviewed and their knowledge/involvement with an active mobility hub.

Participants of the first and second round of interviews are not (necessarily) the same people. The first interviewees are experts in the field of shared mobility and/or mobility hubs. Participants of the second round of interviews are stakeholders who are/were involved with currently existing mobility hubs to share their perceptions on the functioning of the mobility hub. The selection of participants is discussed in the respective chapters. To identify relevant stakeholders and gain an understanding of their roles, a stakeholder analysis is performed.

The interviews will be conducted through an online video call due to the COVID-19 situation. An advantage of online video calls is the integrated opportunity to record the meeting. This has the advantage to save travel time and therefore reduces the threshold for participating. Although Deakin & Wakefield (2014) have described the benefits and drawbacks of Skype interviewing, no significant drawbacks or concerns are foreseen with everyone's recent experiences of working from home and using video conferencing software.

2.4.3. Processing of the interviews

With the consent of the participants, the (online) meetings will be recorded and translated into transcripts. These transcripts are sent back to the interviewee for approval to check that the transcripts are complete. If desired, the participants have the opportunity to make changes. Thereafter, the transcripts are then coded to analyse the qualitative data. "A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2013, p. 3). Subsequently, the codes of all interviews (per interview round) are grouped into themes. These themes are then interpreted and used to draw conclusions. Figure 6 illustrates this process.

There is chosen for this approach as due to the nature of semi-structured interviews, some interviewees talked freely on the topics, not always exactly the same questions are posed, or the sequence of the discussed topics varied slightly. Without any coding and grouping, it would therefore be impossible to compare the interviews and draw a conclusion.

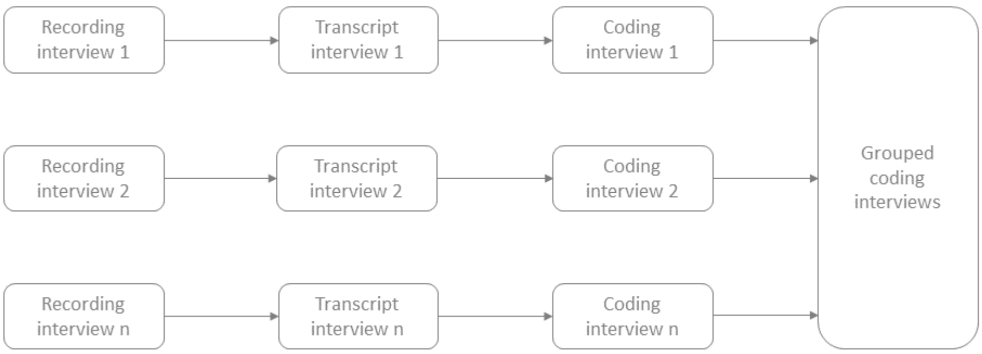


Figure 6: Data analysis interviews process

Mobility hubs – state of the art

3. Mobility hubs – state of the art

In this chapter, the literature review regarding the mobility hub is discussed. First, currently used definitions and categorisation of mobility hubs are explored, followed by an eventual definition for neighbourhood mobility hubs, which are the focus of this research. This is followed by a description of shared mobility types that could be present at a mobility hub. Thirdly, this chapter contains an investigation of existing mobility hubs in the Netherlands and Europe. The final section of this literature review chapter contains an analysis of policy goals and ambitions for shared mobility and mobility hubs. It aims to answer sub-research question 1: *What are the municipal policy goals for shared mobility and mobility hubs, and how can a mobility hub be assessed?* This chapter, therefore, contributes to a better understanding of the research scope and answers the first research question that will form the basis for the next phases of the research.

3.1. Definition and categorisation of mobility hubs

As mentioned in the Introduction, a mobility hub can be viewed on various scales. This section aims to define and categorise different mobility hubs and formulates a definition for the neighbourhood mobility hub, the focus of this research.

3.1.1. Definition of mobility hubs in general

From an investigation of previous research into mobility hubs, it became clear that there are a variety of terms and definitions used for the 'mobility hub' concept. Aono (2019) and Claassen (2019) have rightly touched upon this issue by listing the various definitions and objectives of mobility hubs used by scholars and other jurisdictions. Besides the ambiguity of the term mobility hubs, several other concepts (transport hubs, mobility stations, mobile hubs, etc.) largely overlap in definition. For example, Miramontes (2018) has used the term 'mobility stations' in her research. She concludes that mobility stations are concentrated on the transport supply; thus, they are seen as nodes. The North American definition of mobility hubs combines aspects of the transport supply and land use components and are therefore seen as both nodes and places (Miramontes, 2018). Table 2 provides an overview of definitions used by various researches. This table is not complete but contains an overview of the researches that provided a clear definition of the term in one (or more) lines. Figure 8 contains a visualisation of the used terms with respect to the goals (grey) and location (orange) of mobility hubs.

Table 2: Mobility hub definitions

Mobility hub definitions	Source
"mobility hubs are defined as a place where different sustainable transportation modes are integrated seamlessly to help promote connectivity, and are usually located in centralized areas"	(Aono, 2019, p. 3)
"a location in a residential area, where shared cars, mopeds, e-bicycles and e-cargo bicycles are offered together"	(Claasen, 2019, p. 21)
"mobility hub as a place that provides and connects a variety of different transportation modes, supplemented by enhanced facilities and information functions to attract and benefit travellers"	(CoMoUK, 2019, p. 4)
"A mobility hub is more than just a transit station. Mobility hubs consist of major transit stations and the surrounding area. They serve a critical function in the regional transportation system as the origin, destination, or transfer point for a significant portion of trips. They are places of connectivity where different modes of transportation – from walking to riding	(Metrolinx, 2011, p. 4)

Mobility hub definitions	Source
transit – come together seamlessly and where there is an intensive concentration of working, living, shopping and/or playing."	
"multimodal transport nodes that facilitate intermodal transfers by providing different mobility options in close proximity"	(Miramontes et al., 2017, p. 55)
"A physical location that makes enables the transfer to the most optimal modality for the continuation of the trip" 2	(Mobiliteitsalliantie, 2020, p. 3)
"Mobility Hubs provide a focal point in the transportation network that seamlessly integrates different modes of transportation, multi-modal supportive infrastructure, and place–making strategies to create activity centers that maximize first–mile last mile connectivity"	(Urban Design Studio, 2017, p. 5)
"A neighbourhood mobility hub is a central place where shared mobility is offered, with the goal of decreasing local emission, congestion and car ownership"	(van Rooij, 2020, p. 28)
"on-street locations that bring together e-bicycles, e-cargo bicycles, e-scooters and/or e-cars"	(Interreg, n.d.)
"A Mobility Hub is a recognisable and easily accessible place which integrates different transport modes and supplements them with enhanced facilities, services and information aimed at encouraging more sustainable travel, creating sense of place and improving journeys and travel choices"	(SEStran, 2020, p. 4)
"A Mobihub is a recognizable, physical place where at least two modes of transportation are frequently interconnected". "To be specific, a mobility hub is a location, such as a bus stop or train station, where individuals can enter or exit a mobility mode".	(Storme et al., 2021, p. 5)

Figure 8: Word clouds of goals or services offered (left) and location of mobility hubs (right) based on definitions in Table 1

Summarising, these definitions have in common that the hubs are described as physical locations or nodes that provide access and transfer options to a variety of different (shared) transport modes (multimodal). Some descriptions go a bit further and describe that these nodes are places supplemented with facilities and services such as public transit or that these places can be seen as activity centres. What clearly emerges here is the relation between node and places, or in other words, the interaction between transportation and the built environment. This finding in the definition of mobility hubs is in line with the research of Bertolini (1999), who has developed the Node-Place Model. The model is based on the principle that a transportation node cannot be seen separately from its urban surroundings (place). For a station to be successful, there needs to be a balance between node and place values (Bertolini, 1999). Moreover, these definitions and word clouds comparison again illustrate that hubs can be viewed from different scales and perspectives.

3.1.2. Categorisation of mobility hubs

A Dutch consultancy in the field of urban mobility, Goudappel Coffeng, has identified that categorisation of mobility hubs (in the Netherlands) should be done in two steps: the

[2] Translated from Dutch: "Een fysieke locatie die de overstap(slag) naar de meest optimale modaliteit voor de vervolgreis mogelijk maakt"

geographical location of the hub and the scale at which the hubs functions (Kwantes et al., 2019, 2020). The geographic location can be divided into four zones:

A. Inner-city location
B. Urban residential area
C. City periphery/peripheral zone urban region
D. Regional centres/rural zones

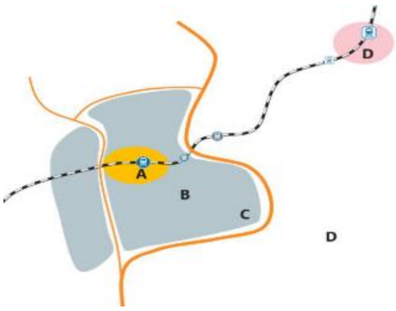


Figure 9: Geographical city zones (APPM & Goudappel, 2020)

In the second step, the scale at which the hub operates is considered. This has to do with the distance people are willing to travel to the hub. This can be divided into four categories:

- Neighbourhood/village
- City
- (Inter)regional
- (Inter)national

Based on this categorisation, eight types of hubs can be identified:

1. National hub: a hub of national importance such as a seaport or airports. At these hubs, various transport modalities come together, and passenger and freight transport often converge (Mobiliteitsalliantie, 2020).
2. City hubs: public transport nodes with high passenger numbers in the (inner-)city for starting/ending journeys and or transferring between modes.
3. City-edge hubs: hubs at the edge of a city where national and regional public transport, car traffic, shared mobility, and bicycles meet. Typical example: P+R facilities.
4. Regional hubs: transfer locations from public transport to car or bicycle in regional or rural zones.
5. Neighbourhood hubs: bundling of services at city district level, mostly in an urban environment. Often in conjunction with urban (re)development (APPM & Goudappel, 2020). Shared mobility services are vital, which modes specifically depends on the location and demand.
6. Business park hubs: hubs focused at commuters, shared mobility provisions for employees arranged by employers and mobility providers (CoMoUK, 2019; Natuur & Milieu, 2020).
7. Logistics hubs: hubs (at the edge of cities) from where goods are transferred in an efficient manner and, where possible, emission-free into the city (van Rooij, 2020).
8. Temporary hubs: In some cases, temporary hubs could be identified. These can be either passenger or freight focussed. An example of a temporary hub is during construction work for the clustering of building materials.

In Figure 10, the categorisation of these eight types of hubs is visualised on the scale of the geographic zone and the scale on which the hubs operate.

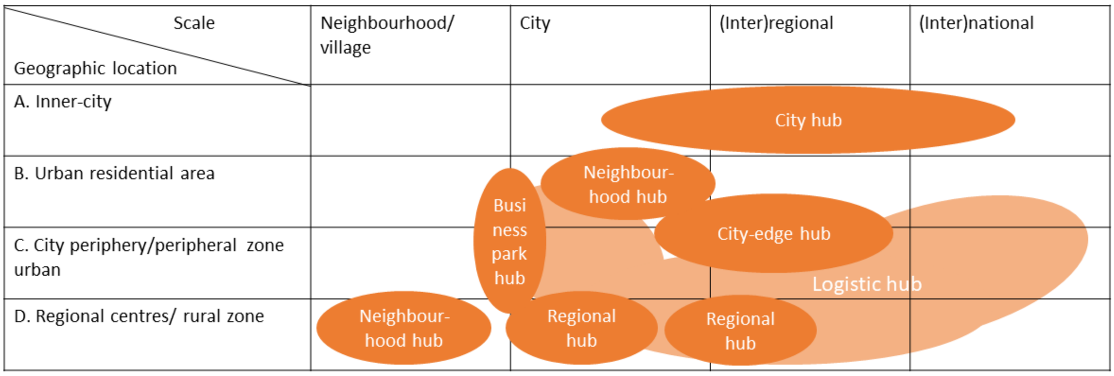


Figure 10: Categorisation of hubs based on scale. Based on (APPM & Goudappel, 2020)

Table 3 on the next page gives an overview of the recommended or vital amenities for these categories of mobility hubs. For the last two categories, a logistics hub and a temporary hub, the table could not be completed due to their varying (and case-specific) goals.

Table 3: Mobility hub amenities. Based on (APPM & Goudappel, 2020; SEStran, 2020; Urban Design Studio, 2017; Zwikker et al., 2021)

Cell values: V = Vital/High quality (blue), R = Recommended/Basis (green), O = Optional (orange); empty = not marked.

		Pedestrian				Cycling							
		Sufficient transfer capacity	Direct walking routes to destinations	Signage	Traffic safety and recognisability	Bicycle lockers	Bicycle parking supervised	Bicycle parking (public space)	Bicycle repair service	Connection to bicycle highway network	Connection to main cycling network	Charging facilities	Traffic safety and recognisability
1	National hub	V	R	V	V	R	R					O	R
2	City hub	R	R	V	R	O	V	R	R	R	V	R	V
3	City-edge hub			R	R	R		R			R		
4	Regional hub	R	R	R	R		O	R	O	O	O	R	V
5	Neighbourhood hub		O		R			R	O		R	R	R
6	Business park hub		O		R	O	O	R				R	
7	Logistics hub												
8	Temporary hub												

		Public transport				Shared mobility					
		Intercity train	Sprinter train	HOV	Bus	Shared cars	Shared LEV	Shared e-mopeds	Shared (e-)bikes	Shared (e-)cargo bikes	Shared e-scooters
1	National hub	V	R	R	R	R	O	O	R	O	O
2	City hub	V	V	V	R	R	O	O	V	O	O
3	City-edge hub			V	R	O		O	R		
4	Regional hub		R	O	R	O			R		
5	Neighbourhood hub			O	O	R	O	O	R	O	O
6	Business park hub				O	R	O	O	R	O	O
7	Logistics hub										
8	Temporary hub										

		Car					Space			
		Parking facilities (paid)	Parking places	Kiss & Ride	Charging facilities	Taxi stand	Mix (type of travellers)	Quality public space	Close proximity living (densities)	Close proximity working (densities)
1	National hub	V		R	O	V	R	V	O	O
2	City hub	R		R	R	R	R	V	V	V
3	City-edge hub		R		R	O	R	R		
4	Regional hub		V	R	R		R	R	O	O
5	Neighbourhood hub		R		V		O	V	R	R
6	Business park hub	O	R		R	O				R
7	Logistics hub									
8	Temporary hub									

		Services					
		Waiting areas	Travel information	Shops	Cafés and restaurants	Toilets	Parcel delivery lockers
1	National hub	V	V	R	R	V	
2	City hub	R	R	R	R	R	R
3	City-edge hub	R	R		O	O	O
4	Regional hub	R	R	O	R	R	O
5	Neighbourhood hub		R	O	O		O
6	Business park hub				O		
7	Logistics hub						
8	Temporary hub						

Legend:
- Vital/High quality
- Recommended/Basis
- Optional

3.1.3. Definition of neighbourhood mobility hub

To conclude this section, this research will focus on the neighbourhood mobility hub like depicted in Figure 11. In the Flemish policy vision on mobipunts (neighbourhood mobility hubs), five performance indicators are identified in order to assess the quality of a mobipunt (BUUR & The New Drive, 2019), these are in accordance with the eHUB technical and functional requirements document (van Gils, 2019a). These themes are:

- Mobility supply
- Services
- Orientation
- Spatial integration
- Development

The mobility supply is the core of a neighbourhood mobility hub, although its size and the diversity of the supply in the different transport modes can vary per hub. From Table 3 follows that these types of hubs are equipped with at least shared cars and shared (e-)bikes and possibly also other shared mobility services. The hub could be connected to public transport, of which the bus and HOV are most likely. With respect to the services, a neighbourhood mobility hub could offer services that add value to the users, such as shops, kiosks and lockers for parcel pick-up. Thirdly, the orientation aspect means that the user should be able to navigate to the hub easily and that these locations are recognisable (BUUR & The New Drive, 2019). The spatial integration of a mobility hub has to do with the quality of the public scape around the hub location; the hub should fulfil the requirements of (traffic) safety, accessibility and liveability. The location of the hub should be in close proximity to the potential users. Research has indicated that the average distance a user is willing to travel to such a neighbourhood mobility hub is a maximum of five hundred meters or within walking distance of five minutes (Bartsen, 2019; Claasen, 2019; Dieten, 2015; Knippenberg, 2019; Natuur & Milieu, 2020; van Rooij, 2020). As follows from Figure 10, the neighbourhood mobility hubs are in either residential areas or regional centres. The final aspect is development, which means that it should be possible to alter the mobility hubs due to new (spatial) developments to fit their environment (BUUR & The New Drive, 2019).

Neighbourhood mobility hub definition

For the purpose of this research, a neighbourhood mobility hub is defined as: a physical location, with a catchment area of approximately 500 meters radius, where a variety of shared mobility services are offered. Of which at least one shared car and one shared (e-)bike.

Figure 11: Impression of neighbourhood mobility hub (Mobipunt, n.d.-c)

3.2. Types of shared mobility

Shared mobility is a crucial aspect of a neighbourhood mobility hub. Shaheen et al. (2017) rightfully describe that shared mobility is an umbrella term and includes the use of a shared car, bicycle, or other modes that enable users to have short term access to transportation modes on an as needed basis. Figure 12 shows a scheme of shared mobility types currently on the market and some of its modalities. The original figure of Shaheen et al. (2020) also contains two extra branches, namely the sharing of a passenger ride and a delivery ride. Because in this thesis, the focus lies on the sharing of a vehicle or device, only this part of the original scheme is depicted and adapted based on (Ferrero et al., 2018; Machado et al., 2018; Münzel et al., 2020; Roukouni & Correia, 2020).

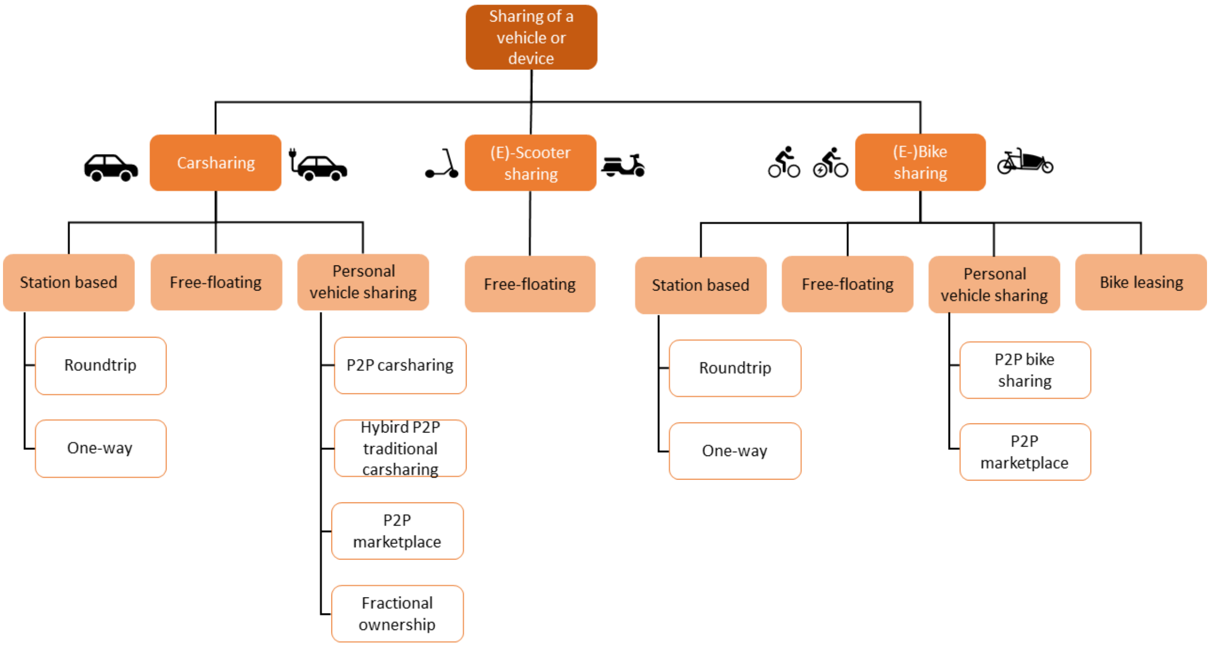


Figure 12: Shared mobility and its modalities (Ferrero et al., 2018; Machado et al., 2018; Münzel et al., 2020; Roukouni & Correia, 2020; Shaheen et al., 2020)

3.2.1. Carsharing

Carsharing is the usage of a vehicle fleet by members of the carsharing provider for making trips on a per-trip basis (Ferrero et al., 2018; Shaheen et al., 2019). As can be seen from the figure, there are multiple types of car sharing. There are generally two models distinguishable, Business-to-Customer (B2C) carsharing, also referred to as 'classic carsharing' and personal vehicle sharing (PVS), which often implies Peer-to-Peer (P2P) carsharing but also increasingly hybrid forms are emerging that blur the line between B2C and P2P models (Münzel et al., 2019).

Ferrero et al. (2018) categorise the 'classic carsharing' into three different ways:

- roundtrip station based: the available vehicles are parked at defined parking locations where the trip starts and ends
- one-way station based: similar to two-way station based, only difference is that the vehicle can be returned to a different predefined station then where the trip started
- free-floating: vehicles are freely parked in the public space, within an operational area, and the trip can start and end at any location within this area.

In PVS carsharing privately-owned vehicles are temporarily made available for other individuals (Shaheen et al., 2020). In P2P carsharing, car owners act as providers of shared cars for which they temporarily make their privately-owned vehicles available to individual members of a P2P carsharing company (Machado et al., 2018; Münzel et al., 2019). Hybrid P2P-traditional carsharing is when a company provides P2P while also maintaining its own fleet of shared vehicles (Shaheen et al., 2020). In a P2P carsharing marketplace situation, direct vehicle interchange is arranged via a platform of a company where vehicle owners and renters discuss the terms and conditions themselves (Shaheen et al., 2020). Fractional ownership is a model of carsharing where a group of people together owns the vehicle (Machado et al., 2018).

3.2.2. Bike sharing

Bike sharing is one of the fastest-growing transportation innovations (Shaheen et al., 2020). Bike sharing system can be split up amongst four quadrants, see Figure 13 (van Waes et al., 2018). One dimension distinguishes whether it is a single or a return trip. Either the trip must start and end at the same location (roundtrip), or it is possible to return the bicycle at a different station than where it is picked up (one-way). The other axis along which bike sharing schemes can be distinguished has to do with parking (van Waes et al., 2018). Station-based or free-floating. Station-based systems mean that users can access the bicycles at fixed stations. In a dockless or free-floating bicycle sharing system, users can access and park the bicycle at any location within the operational area. Currently, only B2C bike sharing services are operating in the Netherlands. No P2P systems exist (van Goeverden & Correia, 2018). In 2015, a new form of bike 'sharing' has emerged in the Netherlands, namely that of a bike-lease system on a subscription basis (Ma et al., 2020; Salvador, 2018).

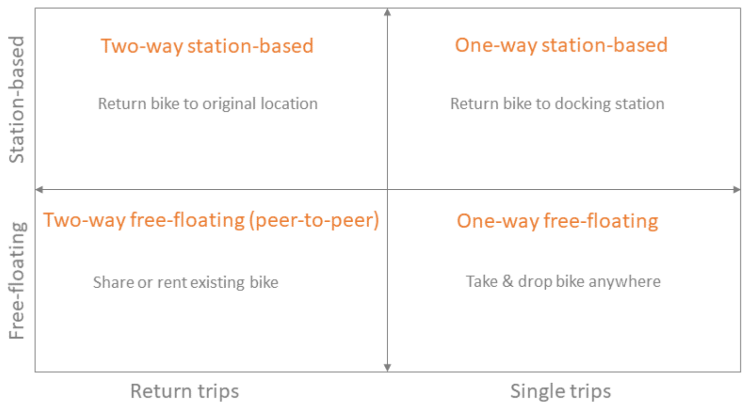


Figure 13: Bike sharing typology (van Waes et al., 2018)

Recently, two new types, electric bicycles (e-bikes) and electric cargo bikes, are added to traditional bike sharing. E-bikes allow for higher speeds at a higher level of comfort and, therefore, may increase bike sharing competitiveness with private car trips and public transport (Guidon et al., 2019). Electric cargo bikes are particularly useful in transporting goods or children, which is a promising alternative for car substitution (S. Becker & Rudolf, 2018; Hess & Schubert, 2019).

3.2.3. Scooter sharing

Shared micro-mobility refers to a motorised individual transport mode of a light, small sized vehicle or device for trips of shorter distance (Eccarius & Lu, 2020). Particularly powered two-wheelers are popular because of their low carbon footprint and less occupied road space (Boot, 2018; Holm Møller et al., 2020). One form of micro-mobility is the scooter. A scooter can refer to two types of transportation modes in English: electric (standing) scooters (*in Dutch: e-steps*), and moped-style scooters (*in Dutch: e-scooter*). Though present in many countries, electric scooters are currently not allowed on the public road in the Netherlands (Boot, 2018). Moped scooter sharing, on the other hand, is fast expanding in the Netherlands and on a global scale (Aguilera-García et al., 2020). Almost all of the scooter sharing services are B2C focussed, 99% are free-floating (Aguilera-García et al., 2020), and 99-100% are electric, excluding the Indian market (Howe & Jakobsen, 2020). Though the scooters are mostly free-floating and therefore not directly linked to a mobility hub, they could still be provided by the hub provider and temporarily parked at the mobility hub.

Figure 14: Electric scooter (van de Laak, 2020)

Figure 15: Electric moped (Thies, 2020)

3.3. Overview of existing neighbourhood mobility hubs

In this section, an overview is presented of active mobility hubs in Europe as well as in the Netherlands and a short description of mobility hub operators in the Netherlands.

3.3.1. Existing neighbourhood mobility hubs abroad

In various cities in Germany, mobility stations have already been implemented several years ago, such as in Munich, Wurzburg, Offenburg, as described by Alarcos Andreu (2017), Heller (2016), Miramontes (2018) and Pfertner (2017) in their theses.

As part of the European collaboration in the North Sea Region SHARE-North project, several mobility hubs (mobil.punkt) are opened in Bremen, Germany and Bergen, Norway (SHARE-North, n.d.).

Similarly, there is an eHUBS partnership is a consortium of 15 parties composed of European cities, network organisations, shared e-mobility service providers, and universities. With a subsidy of the European Union these parties collaborate to realise and promote eHUBS in six partner cities (Amsterdam, Arnhem, Nijmegen, Leuven, Manchester, Kempten, Dreux) (Interreg, n.d.) The e-Mobility hubs, or eHUBS, are seen as a crucial step towards adapting shared and electric mobility services. By sharing the knowledge obtained with the pilots in each partnering city, experiences and best practices are shared. The mobility hubs realised in this project vary in size, type of location and type of transport services offered (Interreg, n.d.). An overview of foreign cities with active neighbourhood mobility hubs is given in Table 4.

Table 4: Overview of foreign cities with active neighbourhood mobility hubs

Country	Hub name/provider	City
Belgium	Mobipunt	Leuven
Germany	Smart e-mobility station	Munich
Germany	Mobilstationen	Wurzburg
Germany	Einfach Mobil	Offenburg
Germany	Jelbi	Berlin
Germany	Mobil.punkt	Bremen
Germany	MOBIpunkte	Dresden
Germany	Leipzig mobil	Leipzig
Germany	Switchh punkte	Hamburg
Germany	Mobilpunkte	Nuremburg
Germany	KombiMoll	Graz
Germany	Mobilpunkte	Kempten
Norway	Mobil.punkt	Bergen

3.3.2. Existing neighbourhood mobility hubs in the Netherlands

In the last two years, many mobility hubs are opened in the Netherlands. Which is partly due to two European projects alongside some hubs that are realised by mobility providers. Currently, there are around 160 small scale mobility hubs in the Netherlands that contain shared cars, (e- and/or cargo-)bikes. Of which 90 are publicly accessible, and another 60 are private, meaning that the hubs are the shared vehicles are only accessible for a designated group of residents and/or employees. Table 5 lists some mobility hub providers, how many hubs they have and where. This section below discusses some of the mobility providers.

Table 5: Overview of (number of) public mobility hubs in the Netherlands (July 2021) (Amber, n.d.; eHUB Arnhem, n.d.; eHUB Nijmegen, n.d.; Hely, n.d.-c; Juuve, n.d.; MOBIAN, n.d.; Mobipunt, n.d.-b; reisviahub, n.d.)

Hub name/provider	Cities (number of hubs)
eHUBS	Nijmegen (10), Arnhem (3), Amsterdam (3)
Mobipunt	Alkmaar, Anna Palowna (2), Den Helder (4), Den Oever, Medemblik, Middenmeer (2), Schagen (2), 't Veld, Wieringerwerf
Hely	Amsterdam (4), Delft, Den Haag (2), Ede, Haarlem, Rotterdam, Utrecht (2), Helmond
Juuve	Benschop, Schiedam (4), Utrecht
Amber	*Various places across the Netherlands (47)*
MOBIHUB	Amsterdam (2), Den Haag, Eindhoven, Rotterdam (2), Utrecht
Reis via hub	*Various locations in Drenthe and Groningen (58)*

eHUBS

As part of the eHUBS project are, in June 2020, ten eHUBS opened across various locations in Nijmegen. The hubs offer shared electric vehicles, electric bicycles and electric cargo bikes, the exact configuration of the hubs differs (eHUB Nijmegen, n.d.). Similarly, three eHUBS opened in Arnhem (eHUB Arnhem, n.d.). Amber provides the electric cars in the hubs, the e-bikes by Urbee and the cargo-bike are from Cargoroo. Every hub is, at least, equipped with a few e-bikes and, in some cases, also a cargo bike and/or car.

Eventually, also in Amsterdam, ten to fifteen 'BuurtHubs' are planned to be realised between 2019 and 2021. These hubs can vary in size, transport modes offered and services. The residents themselves will compose their hub (Gemeente Amsterdam, n.d.-a, n.d.-c). Table 24 in Appendix B shows the currently active eHUBS in the Netherlands and their configuration.

Mobipunt

The concept of a Mobipunt is developed within the Interreg North Sea Region Project 'SHARE-North'. The SHARE-North programme is aimed to provide shared mobility solutions for a liveable and low-carbon North Sea Region. Various project consortium members, ranging from public authorities to universities, shared mobility providers, and consultants, collaborate to realise local mobility hubs (SHARE-North, n.d.). In the Netherlands, these mobility hubs are called 'mobipunt'. These locations are often close to public transport and provide shared bikes and/or shared cars (Mobipunt, n.d.-a). There are currently 15 mobipunts that offer a couple of shared bikes and shared cars at some locations (see Table 25 in Appendix B). Uwdeelfiets provides the shared bikes, and the cars are from Justlease (Mobipunt, n.d.-b). The ambition is to have 40 mobipunts at the end of 2021 and to expand some of the existing hubs (Mobipunt, n.d.-a).

Hely hubs

Hely is a Dutch Mobility-as-a-Service provider, with PON and the Dutch Railways (NS) as stakeholders, that provides multimodal hubs. Hely aims to make mobility more sustainable, increase the liveability in cities and provide passengers with flexibility. Hely does this by providing their mobility services at various locations through one smartphone app (Hely, n.d.-a). They collaborate with carsharing provider Mywheels. Urbee and Gazelle for the shared e-bikes and Cargoroo and Urban Arrow for the provision of the cargo bikes. Hely is expanding and currently operates 13 public Hely hubs and another 11, which are only accessible for closed user groups such as residents of one building. Table 26 (Appendix B) displays the active Hely hubs in the Netherlands.

Juuve

Juuve is a carsharing provider that accommodates free-floating car sharing (within service areas) but is increasingly involved in creating hub locations and combining carsharing with other shared mobility services. Currently, Juuve is involved in 14 hubs across the Netherlands (Juuve, n.d.). In July 2021, Juuve has announced its merger with carsharing provider MyWheels (Juuve, 2021).

Amber

Amber is a fast expanding carsharing provider that provides its electric vehicles at various 'hub' locations in the Netherlands as well as a free-floating service in some cities. At the moment, Amber cars are available at 47 public hub locations and another 43 private hub locations (Amber, n.d.). At these private locations, the Amber cars are only available to employees of a specific company. Most of the time, the cars are parked in their closed parking garages. Amber hubs do not fall completely within the scope of this thesis as their hubs only contain cars. However, they do cooperate with the eHUBS project in Nijmegen, Arnhem, and Amsterdam.

MOBIHUB

MOBIHUB is a mobility hub concept from MOBIAN that expands the P+R concept with shared (electric) bicycles (and in the future also shared cargo bikes and cars). The MOBIHUB concept offers users free parking for their private car and only charges the use of the shared bicycle with which users can travel the last mile (Mobiliteitsplatform, 2021). Moreover, they recently rolled out a new concept where residents and companies can have a subscription to all MOBIAN's mobility services (MOBIAN, 2021). Currently they operate MOBIHUBS on the city edges of Amsterdam, Rotterdam, Den Haag, Utrecht and Eindhoven (MOBIAN, n.d.).

Reis via hub Drenthe & Groningen

In the provinces of Drenthe and Groningen, there are mobility hubs developed at 58 locations (Natuur & Milieu, 2020). The hubs facilitate the transfer between transport modes (car, bike, public transport, taxi), and various amenities (like Wi-Fi, water, kiosk, charging infrastructure for car and bike, and lockers (for parcel pick-up)) are present to make this transfer more comfortable (reisviahub.nl, n.d.). In contrast to the other hubs discussed in this section, shared vehicles are not available at these hubs.

3.4. Previous research on neighbourhood mobility hubs

This section lists the (limited number of) theses research that have been conducted on the (potential) impact of neighbourhood mobility hubs in the Netherlands. These researches listed below are used in the literature review on usage factors and effects (section 4.1).

- The TU Delft master theses of Knippenberg (2019) and Van Rooij (2020) both focus on the potential users, their perceptions and travel behaviour of mobility hubs. They both looked at several Hely hubs in the Netherlands. They both conducted a literature research, used quantitative data where possible and conducted a user survey. Knippenberg's research focus was on the characterisation of travel behaviour of the Hely community. Relevant findings of these researches are discussed in section 4.1.
- Brooijmans (2020) did an explorative research into the societal feasibility of a mobipunt considering the perspective of different stakeholders and users. Brooijmans identified some crucial determinants for success, namely, (1) the concentration of different functions at one location, (2) low parking standards and restricted parking policy in the mobipunt area, (3) collaboration between the stakeholders in the implementation process.
- Mouw (2020) did his bachelor thesis research on the possible application of a mobility hub in Achtersluispolder. He examined the characteristics of hubs and their users and developed three different scenarios, and assessed them to finally be able to recommend the most desired scenario for the case study Achtersluispolder.
- Claasen (2019) researched the intention to use a mobility hub of residents across two different neighbourhoods in The Hague and their potential effect on household car ownership. One of his main findings is that residents are more likely to use their own car than one of the shared modes provided at the mobility hub. When they do choose shared mobility, the shared car is the most popular mode. Furthermore, Claasen found that there is a potential household car ownership reduction of 8%-15% as a consequence of a mobility hub nearby.

Next to the Dutch studies, there are also several pieces of research on mobility hubs in Germany:

- In Miramontes' (2018) doctoral research study, she has researched the assessment of mobility stations by exploring state of the art and investigating pilot projects of mobility stations in Germany. As part of her research, several master theses are conducted on the effects of mobility stations in individual cities.
    - Luginger (2016) aimed to identify success factors for the implementation of mobility stations by a literature review of four German case studies (Bremen, Hamburg, Offenburg, Leipzig).
    - In Heller (2016)'s master thesis, she evaluates the mobility station in Offenburg. Based on an empirical study and perception and acceptance of the new integrated multimodal mobility service, the needs for mobility, and

the (potential) change in mobility behaviour of users and non-users are analysed.
  - Alarcos Andreu (2017)'s research focused on a small private mobility station in the district of Dogmagkpark (north Munich). He evaluated the impact using a survey among the district inhabitants and analysed the implementation process through stakeholder interviews.
  - Pfertner (2017) evaluated the concept of a mobility station in the German city of Würzburg. He analysed the mobility stations concept and estimated and surveyed the effects of the mobility stations on the user's mobility behaviour and car ownership.
- In the article of Miramontes et al. (2017), the acceptance and mobility behaviour of mobility stations in Munich are evaluated. They found that the majority of the mobility station users is young, male and highly educated. The users have a multimodal travel behaviour and have access to multiple mobility options, of which public transport plays a central role. Mobility stations have improved the availability of other mobility services, which the users appreciate.
- The article of (Miramontes et al., 2019) provides a short summary of the researches on the mobility stations in Munich, Offenburg and Würzburg (as discussed above).
- Schreier et al. (2018) has conducted a research into the impact of shared mobility that is provided via the mobility hubs in Bremen. Though this mostly focuses on carsharing, it is very valuable research for the literature review in chapter 4. The research has shown very positive impacts of carsharing in Bremen in terms of private car ownership, reduced traffic and increased use of sustainable modes.

These studies are used in the remainder of this chapter to identify the factors influencing the usage of mobility hubs and the contribution of mobility hubs to policy goals.

3.5. Societal goals and ambitions of mobility hubs

This section describes the policy goals that have led to the introduction of mobility hubs. Therefore, this section also provides an answer to the second research question 1: *What are the municipal policy goals for shared mobility and mobility hubs, and how can a mobility hub be assessed?*

3.5.1. Sustainable mobility goals in literature

"Promoting sustainable mobility is one of the most widespread objectives in transport policy" (Gallo & Marinelli, 2020, p. 1). The objective of sustainable mobility can be described as ensuring that the transport systems meet society's economic, societal and environmental needs while also minimising the undesirable impacts. And not only is sustainable mobility a hot topic in policymaking but also scientifically, there is much interested in the subject (Gallo & Marinelli, 2020).

Jones et al. (2018) describe three city's authority perspectives and stages of urban transport policy development process. Most large cities in Western Europe have followed this typical process (Teoh et al., 2020), with first the city planning being focussed on accommodating the use of private cars (Stage 1: a car-oriented city (C)). When the negative consequences of private car use became evident, the cities shifted from moving vehicles to moving people in the second stage (M), the sustainable mobility city. Finally, the focus of policies moves to improving the quality of life (stage 3, P: city of places).

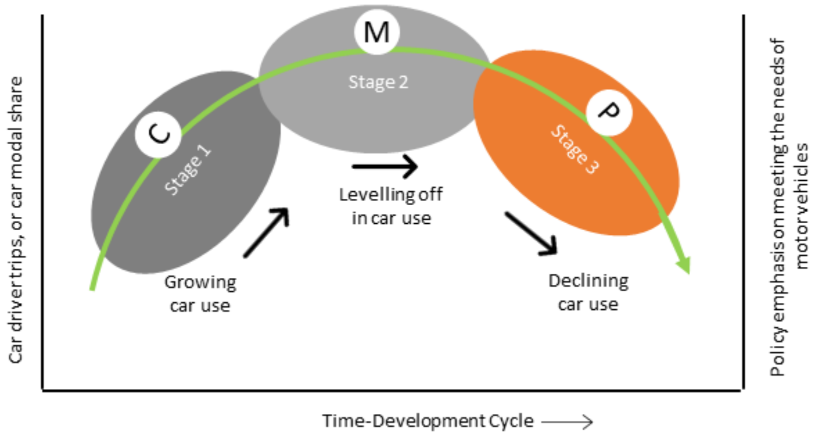


Figure 16: 3-stage urban transport policy development process (Teoh et al., 2020)

This third stage of declining car usage is also often called the 'mobility transition'. The technological developments in smart devices have accelerated this transition and have contributed to the growing popularity of shared mobility (Meng et al., 2020). As mentioned in the introduction, this third stage can be broadly categorised into the four actions of (Banister, 2008):

- Reducing the need to travel
- Transport policy measures
- Land-use policy measures
- Technological innovation

Measures in the first category result in a reduction in the number of trips. This could either be through substitution with a non-travel activity or through the replacement of new technologies, like working from home or online shopping (Banister, 2008). The second category of transport policy measures include policies that reduce car use in favour of active and sustainable travel modes such as walking, cycling and public transport. Examples of measures within these policies are car-free areas, emission zones, parking measures or tolling and road pricing (Banister, 2008; Benevolo et al., 2016; Canitez et al., 2020; Macário & Marques, 2008; Pinna et al., 2017). The category of land-use policy concerns measures that address the physical separation of activities that are more land-use than mobility related but undeniably impacts people's mobility behaviour (Banister, 2008). Finally, the fourth category relates to measures that impact the transportation sector by using new technology, such as the electrification of vehicles and shared mobility and MaaS applications.

As beforementioned in the introduction, literature has described promising impacts of shared mobility that could contribute to this mobility transition to create sustainable mobility in cities. The sharing economy is based on business models that exploit underutilised assets by replacing ownership by access (Chen & Kockelman, 2016; Machado et al., 2018). In scientific literature, there is much evidence that shared mobility has strong potential to bring numerous benefits and positive effects to cities, such as a more sustainable environment, fewer trips, modal shift, distance reduction and less need for parking space (Machado et al., 2018; Roukouni & Correia, 2020).

In theory, shared mobility, and especially carsharing, can accommodate for individualised transport in a more sustainable manner by foregoing car purchase and driven kilometres, decreasing the demand for cars and parking and decreasing emissions. These emissions are lowered because carsharing adopters are multimodal mobility system users and drive on average less kilometres and the average carsharing vehicle is newer and cleaner (Chen &

Kockelman, 2016; Münzel et al., 2020). But also, bike sharing and other forms of micro-mobility have been regarded as potential to achieve objectives. "In a wider understanding, shared mobility can be defined as trip alternatives that aim to maximize the usage of mobility resources that a society can pragmatically afford, disconnecting their usage from the ownership" (Machado et al., 2018, p. 5)

3.5.2. Policy documents analysis

Many cities are introducing shared mobility as one of the measures for their policy objectives for a more sustainable and liveable city. In order to get more insight into what different Dutch municipalities perceive as their policy goals and how shared mobility can contribute to those, a content analysis is done into policy documents from Dutch municipalities with mobility hubs[3] supplemented with other cities in the top ten of largest municipalities (G10) (CBS, 2021). In these documents, there is looked for goals or ambitions for shared mobility or mobility hubs specifically. Due to the fast developments in the field of shared mobility, a requirement is set that these policy documents must be recent, not older than 2018. Policy documents are found via Google search or municipal websites. The documents are then scanned for the usage of the words "deel*", "deelmobiliteit", "hubs", when these words appear in the text, there is looked for concrete goals or objectives.

The twenty-two policy documents and goals that have been extracted from this analysis are put in Table 6. The translated statements about the policy goals in these documents are presented in Table 29 and Table 30 of the Appendix E.

Table 6: Municipal documents for policy goals analysis

Mobility hub provider or large municipality	Municipality	Documents (Dutch title)	Source
eHUB	Arnhem	*Soon expected new document, not yet published*	-
	Nijmegen	Ambitiedocument Mobiliteit Nijmegen	(Nijmegen, 2019)
eHUB & Hely	Amsterdam	Agenda Autodelen	(Gemeente Amsterdam, 2019a)
		Deelmobiliteit, kansen voor de stad	(Gemeente Amsterdam, 2019b)
		Programma Smart mobility 2019-2025	(Gemeente Amsterdam, 2019c)
Hely	Alkmaar	*No relevant document found*	-
	Delft	Mobiliteitsprogramma Delft 2040	(Gemeente Delft, n.d.)
		Mobiliteitstranisitie Delft	(Gemeente Delft, 2019)
	Den Haag	Nota Smart mobility visie Den Haag	(van Asten, 2021)
		Smart mobility visie Den Haag	(Gemeente Den Haag, 2020)
	Ede	*No relevant document found*	-
	Haarlem	Startnotitie beleid autodelen Haarlem	(Bogaert, 2019)
		Mobiliteitsbeleid Gemeente Haarlem (inspraakversie)	(Gemeente Haarlem, 2021)
	Rotterdam	Fietskoers 2025 Gemeente Rotterdam	(Gemeente Rotterdam, n.d.)
		Rotterdams klimaatakkoord mobiliteit	(Energieswitch, n.d.)

[3] eHUBs, Hely, Juuve or Mobipunts (location with both shared bikes and cars). Amber hubs, MOBIHUB and Reisviahubs are not included because they fall out of scope with respect to the definition of neighbourhood mobility hubs.

Mobility hub provider or large municipality	Municipality	Documents (Dutch title)	Source
		Rotterdamse mobiliteitsaanpak	(Gemeente Rotterdam, 2020)
Hely & Juuve	Utrecht	Mobiliteitsplan Utrecht 2025: Slimme routes, slim regelen, slim bestemmen	(Gemeente Utrecht, 2019)
		Mobiliteitsplan 2040 (inspraakversie)	(Gemeente Utrecht, 2020)
Juuve	Lopik	*No relevant document found*	-
	Schiedam	Mobiliteitsvisie Gemeente Schiedam	(Gemeente Schiedam, 2020)
Mobipunt	Hollands Kroon	Mobipunten in de Kop van Noord-Holland	(Metz & van der Meché, 2020)
	Den Helder	*No relevant document found*	-
	Schagen	*No relevant document found*	-
G5	Eindhoven	Agenda Deelmobiliteit Eindhoven	(Gemeente Eindhoven, 2019)
G6	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)	(Gemeente Groningen, 2021)
G7	Tilburg	*No relevant document found (current document from 2016)*	-
G8	Almere	Mobiliteitsvisie 2020-2030 Almere	(Gemeente Almere, 2020)
G9	Breda	Gemeente Breda deelmobiliteit	(Weallwheel, n.d.)
		Mobiliteitsvisie Breda	(Gemeente Breda, 2020)

Shared mobility policy goals

In general, based on the interpretation of the author, the policy goals for shared mobility can be broadly divided into four categories. The statements extracted from the policy documents can be viewed in Table 29 and Table 30 in Appendix E. Figure 17 shows the identified four categories for shared mobility and the statements that fall into these categories. The identified four categories are:

1. Improvement of public space: reduce current pressure on public space, free up public space, improve quality of public space
2. Sustainable and liveable environment: reduce emissions, improve air quality, achieve climate goals,
3. Reduction of (private) car usage and ownership
4. Improvement of accessibility: improve accessibility and connectivity, enrichment of mobility options

These four policy themes are interconnected. When car usage decreases, fewer greenhouse gases are emitted, contributing to a *sustainable and liveable environment*. However, when the goal is to decrease *car usage*, other mobility options must be provided, and the *accessibility* of common trip destinations (with other modes than a car) should be guaranteed. On the other side, the *accessibility* of some destinations could also increase due to reduced traffic delays. And thirdly, when also the *car ownership* decreases, public (parking) space is becoming vacant, making it possible to make something else can be made of the old parking lot like a small green space that improves the urban aesthetic of the *public space*. Although these objectives are closely linked, they are also separate main objectives as they are individually mentioned in most of the policy plans.

Accessibility is a broad theme, and within the policy documents, it actually contains two subjects, namely ensuring accessibility of certain destinations or public transport. Secondly, *accessibility* also refers to increasing the mobility options by providing shared mobility in the city. It is therefore about providing alternatives for conventional travel modes and promoting sustainable and multimodal travel.

Identified statements from the documents are depicted in Figure 17, including how many times they are mentioned in the twenty-two documents as listed in Table 6. Next to the four coloured categories, Figure 17 also contains a grey category of 'other & multiple categories'. This means that these are relevant statements that either could not be clearly devoted to one category or fit in multiple.

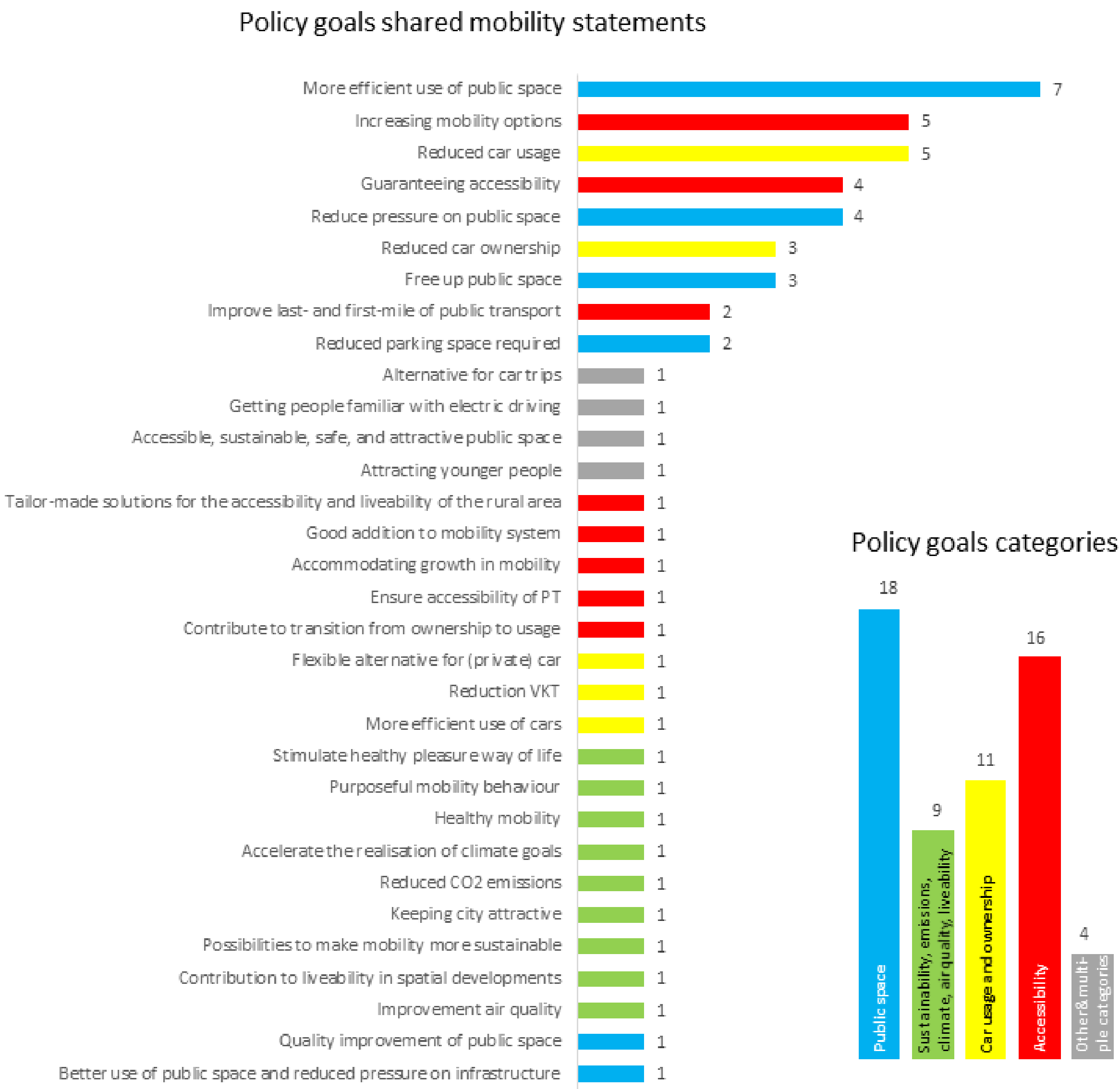


Figure 17: Shared mobility policy goals statements and the number of times mentioned in policy documents, sorted by categories. Statements including sources are represented in Table 29 (Appendix E).

Mobility hub policy goals

Only nine municipalities explicitly mentioned the goals of a mobility hub. The mentioned policy goals of mobility hubs (Figure 18) in the municipal documents seem to be often related to multimodality. Mobility hubs can play an important role in facilitating or stimulating multimodal trips. As the documents mention, shared mobility can improve the accessibility of public transport and improve the last- and first mile. Mobility hubs especially are then a place to facilitate the transfer. In this context also often Mobility as a Service (MaaS) is mentioned in the policy documents. As also stated in one of the policy goals, mobility hubs and shared mobility reinforce each other. Therefore, mobility hubs can be viewed as an enabler of the goals set for shared mobility.

Identified statements from the documents are depicted in Figure 18, including how many times they are mentioned. Figure 17 also contains five coloured categories, just like Figure 17 with the purple 'multimodality' category as extra. The grey category of 'other & multiple categories'. This means that these are relevant statements that either could not be clearly devoted to one category or fit in multiple.

Figure 18: Mobility hub policy goals statements and the number of times mentioned in policy documents, sorted by categories. Statements including sources are represented in Table 30 (Appendix E).

The identified policy goals and themes regarding shared mobility and mobility hubs are largely in line with common goals for the implementation of mobility stations in German cities, as Miramontes (2018) has summarised. She states that "the implementation of mobility stations has the goal of promoting ecomobility, offering alternatives for private cars, and with that, a reduction in private car ownership and usage. Others goals are to promote the efficient use of mobility options by demonstrating the benefits to the environment and the users." (Miramontes, 2018, p. 68)

The mobility hub strategy for the South East of Scotland region has identified similar mobility hubs' key objectives. They summarised the objectives in four themes; economy, accessibility, environment, and safety and health. The economy aims to improve connectivity by integrating transportation options and services and integrating shared mobility in the existing transport network. The objective accessibility consists of threefold: improve accessibility to provide more transport options (for people without access to a private car), promote inclusivity, and support people to make informed travel choices. The theme *environment* contains goals such as reducing emissions, increasing the use of shared mobility as an alternative to private cars, and facilitating a modal shift to sustainable and active travel modes to reduce car ownership. Safety and Health aim at reallocating space in the public realm and create a sense of place and community (SEStran, 2020).

3.5.3. Discussion policy goals and ambitions

What became clear from this analysis is that all municipalities acknowledged their challenges in finding a balance between mobility, a sustainable, liveable, and healthy city. Some cities also simultaneously have to cope with a growing population and densification. And while almost all municipalities mention shared mobility as a measure or enabler of the mobility transition, this is not clearly linked to policy goals in some policy plans. Or sometimes, shared mobility is simply regarded as a trend or goal in itself. For example, in October 2019, the municipality of Haarlem wrote that they did not have a policy for carsharing yet. "In general, we respond ad hoc to car-sharing initiatives". The municipality facilities classic and peer-to-peer carsharing, or when carsharing is provided as a mobility concept in a development project (Bogaert, 2019). The recent (draft) mobility policy of Haarlem has still a relatively small role for shared mobility. Introducing shared mobility and mobility hubs could be one of the measures for behavioural intervention to change mobility by increasing convenience, attractiveness, social pressure and good timing (Gemeente Haarlem, 2021).

The underlying goal to which shared mobility could specifically contribute is still vague. Similarly, Nijmegen says that they do collaborate with different shared mobility initiatives "provided that they respond to a specific demand from the city or district and meet minimum quality requirements" (Nijmegen, 2019, p. 31). At first instance, they do not explicitly mention policy goals.

Concluding, shared mobility and mobility hubs are sometimes seen as a goal itself instead of a means to achieve a policy goal. Besides, the coherence between different measures lacks, and they are all very positive inserted. A critical reflection on any negative side effects has not been disclosed.

3.5.4. Conclusion policy goals and ambitions

Promoting sustainable urban mobility is one of the most important objectives in the current transport policies. Most policies today focus on moving people instead of vehicles and thereby improving the urban quality of life. Partly due to technological developments, shared mobility is perceived as a potential solution or measure to accommodate individual transport while promoting sustainable mobility, reducing emissions and pressure on the public space. This concept is not only described in the scientific literature, but increasingly so, shared mobility is covered in policy documents.

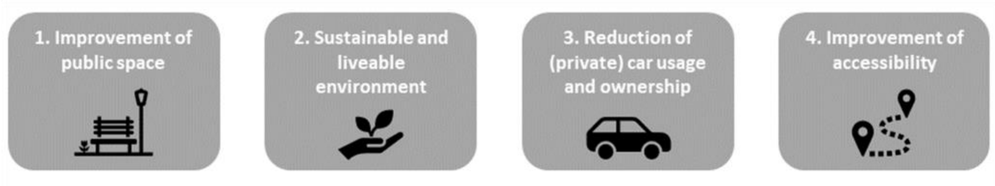
A content analysis of policy documents from various Dutch municipalities is done to explore how these municipalities perceive (the potential of) shared mobility and mobility hubs and, if applicable, which policy goals are coupled to these concepts. From this analysis follows that while 'shared mobility' is an often described subject, not always linked to policy goals, and mobility hubs specifically are even covered less often. However, mobility hubs can be seen as an enabler of the goals for shared mobility and therefore, these goals can be indirectly linked to mobility hubs. In the identified statements, there are four main themes distinguishable: public space improvement, sustainable and liveable environment, reduction of (private) car usage and ownership, improvement of accessibility. These themes could thus also be used to evaluate and assess the effectiveness of a mobility hub.

The policy goals in the category of *improvement of public space relate to more efficient use of public space and reducing* parking pressure. Moreover, by freeing up space that is currently used by cars, more space becomes available, which can be transformed into green or seating that, in the end, improves the quality of the public space or liveability. This is closely related to the category of *sustainable and liveable environment,* which in addition also includes policy goals with respect to emissions, air quality. The policy theme *reduction of* *(private) car usage and ownership* are, as the title suggests, aimed at declining private vehicles. The policy goals in the category of *improvement of accessibility* either relate to ensuring the accessibility of certain destinations and improving public transport connections and or increasing the mobility options for people by providing shared mobility. It is therefore about providing alternatives for conventional travel modes and promoting sustainable and multimodal travel.

1. What are the municipal policy goals for shared mobility and mobility hubs, and how can a mobility hub be assessed?

Answering the first research question, in this thesis the effectiveness of a mobility hub is assessed based on their contribution to the four themes of shared mobility policy goals: improvement of public space, sustainable and liveable environment, reduction of (private) car usage and ownership, improvement of accessibility.

The four themes displayed in the grey boxes are perceived as the key objectives of a mobility hubs and will therefore, in this research, be used for the assessment and evaluation of the effectiveness of mobility hubs. These four objectives will thus also have an important role in the (initial) causal loop diagram as it is expected that the usage factors of a mobility hub will eventually lead to effects in these four themes.



Literature on influencing factors and effects of mobility hubs

4. Literature on influencing factors and effects of mobility hubs

This chapter discusses the findings in the literature on influencing factors and effects of mobility hubs. First, there is started to specifically look into mobility hub researches. But as these are limited, section 4.2 focuses on shared mobility usage and effects in general. Together, this chapter gives insight into sub-research question 2: *What are the factors explaining the usage and effects of neighbourhood mobility hubs in literature?* The research question itself is answered with the help of the initial causal loop diagram in section 5.2.

4.1. Mobility hub literature

This section aims to give an overview of factors that influence the choice to use a mobility hub (section 4.1.1) and the effects of mobility hubs (section 4.1.2). The introduced researches in section 3.4 are used as references.

4.1.1. Influencing factors mobility hub usage

This section provides an overview of the (potential) influencing factors for mobility hub usage. This is split up into four categories that investigate the user perceptions, hub amenities, contextual factors, and user characteristics.

Mobility hub user perceptions

A mobility hub can have different characteristics, as described in section 3.1. These characteristics, what they offer and added value compared to the situation before the mobility hub are crucial in how it is accepted, perceived, and used (Miramontes, 2018). Based on studies of German mobility stations, the success factors for the users' acceptance of mobility hubs are (Miramontes, 2018; Miramontes et al., 2017):

- Location on public space: a mobility hub located on the public space ensures physical access, high visibility, and awareness.
- Fixed location of shared mobility services and spatial concentration of diverse mobility services: having a designated and fixed location for the shared mobility offer adds value compared to free-floating services. Also, the spatial integration of various shared mobility modes supports multimodal mobility behaviour and intermodal trips.
- Electric mobility: the provision of electric mobility options, and especially electric carsharing, has a positive acceptance on both users and non-users of the mobility hubs and is one of the main reasons for using the hub.

More detailed, Van Rooij (2020) identified fourteen important design attributes of a mobility hub: diversity, availability, ease of use, visibility, safety of the hub and vehicles, state of the hub and vehicles, distance to the hub, costs of the hub and vehicle, sustainability of the hub and vehicles and if the hub is part of a network. Mouw (2020) elaborates on this list by reviewing other studies on mobility hubs and carsharing and concludes that the distance to the hub is one of the most important factors. Previous research found that people are willing to travel a maximum of 300 to 500 metres (Bartsen, 2019; Claasen, 2019; Dieten, 2015; van Rooij, 2020). Although included in the list of Van Rooij, the costs are not ranked as the top criterium. Other studies have found the costs to be the second most important factor in the usage of a mobility hub (Bartsen, 2019; Claasen, 2019; Dieten, 2015). Knippenberg's research on motives for Hely hub users found that the main reasons are flexibility and convenience, followed by costs and sustainability (Knippenberg, 2019).

While the experts interviewed by Van Rooij (2020) suggested that the hub should offer a variety of modes, in practice, the presence of a shared car is the far most important system characteristic in the choice for a mobility hub followed by the e-bike. And an e-cargo bike is considered less important (Claasen, 2019; Mouw, 2020). Knippenberg (2019) confirms this as 79% of the total trips of Hely hubs is conducted by car. The fact that the cargo bike is relatively little used (Knippenberg, 2019) contrasts with the experts' expectations in their interviews. The cargo bike is explicitly mentioned as an important mode because the experts perceive the cargo bike as having a high potential to reduce short car trips (van Rooij, 2020).

Mobility hub amenities

Heller (2016) let survey participants (bike sharing users, carsharing users, citizens, commuters) rank the importance of several components of mobility stations in Offenburg. This has resulted in the following ranking, which can be seen as a rough estimate of the importance of the different components and offers of a mobility hub. The percentages mean that the respondents in Heller's survey indicated that the components are 'very' or 'rather important'. Figure 19 shows that public transport connections are seen as the most important component of mobility stations, followed by carsharing, bike sharing and parking places for private bikes. The components rated the least important are taxi stops, kiosks, and a snack bar.

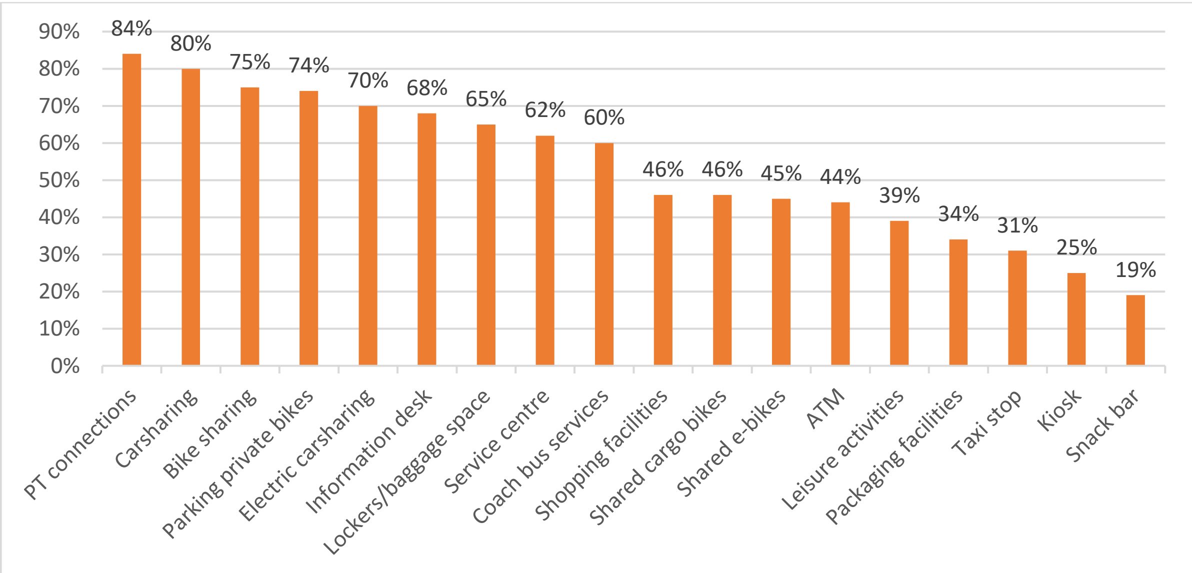


Figure 19: Ranked importance (very or rather important) of mobility station components (Heller, 2016)

Comparison mobility hub categorisation and amenities Table 3 on page 20

Table 3 in section 3.1.2 has presented a categorisation of six mobility hub types and their amenities. Surprisingly, public transport is valued the most important, while in Table 3, HOV and bus are only categorised as 'optional'. The other remarkable amenity is the locker space. While this is perceived as quite important based on Heller's survey, Table 3 does not mention this. Nevertheless, the categorisation of shared mobility services, travel information desk, shops, cafés and restaurants match.

Contextual factors

Based on the mobility station in Germany, Miramontes (2018) has identified five contextual factors that might contribute to a successful mobility hub:

- Pressure on the transportation system and available resources: the policy goals for the implementation of shared mobility and mobility hubs are often triggered by pressure on available resources and the existing transportation system, such as the pressure of available public space, maximum capacity of the road or public transport network or pressure on the environment.
- Cultural change: a common trend is the increasing acceptance of shared mobility services and the fact that private cars are increasingly less perceived as a status symbol.
- Existing shared mobility services: having already existing mobility services in the city facilitates the implementation of mobility hubs. Having a wide variety of shared mobility services might also increase the success of a mobility hub.
- Good public transport supply as the backbone: as shared mobility services are often used in combination with public transport, having a good public transport supply supports the uptake of shared mobility and thus mobility hubs.
- Favourable political and administrative conditions: mobility hubs need political support, favourable administrative conditions, and financing for the hub to be successfully implemented.

Mobility hub user characteristics

Subscribers of the Dutch Hely hubs are mainly young people between 25 and 34 years that live in a two-person household or with children. Slightly more males are subscribed than females. Most of Hely's clientele work on a full-time basis and are relatively highly educated (Knippenberg, 2019). On the other side, Van Rooij (2020) finds that low income and low educated people are more likely to be hub users. This, in combination with the characteristic that the most likely hub user does not own, or has access to a private car, and already have experience with using shared mobility. Moreover, people having a positive attitude towards carsharing and sustainable transport modes are more likely to choose a mobility hub (Claasen, 2019; Miramontes et al., 2017).

The typical user profile for the mobility station in Munich and Würzburg are similar to the Hely users, highly educated males. One point of difference is that Pfertner (2017) notice that two-person households without children are the most common users of the mobility station in Würzburg.

- 50% of the respondents in Munich is between 18 and 29 years old, and another 27% is between 30 and 39 years old (Miramontes et al., 2017). This is similar to Pfertner (2017) with a sample of Würzburg users that are between 20 and 50 years old and a median of around 35 years old
- 37% of Munich survey participants have a private car available at all times, 30% sometimes, and 33% never. The average number of cars available per household is 0.76 (Miramontes et al., 2017).
- The mobility station survey in Offenburg finds a slightly different demographic user profile; 52% of the participants with no access to a private car, and the average number of cars per household is 0.65 (Heller, 2016).
- In Würzburg, 60% of the bike and carsharing users does not own a private car (Pfertner, 2017).

The percentages of users without a private car thus range between 37% and 60% in the three German cities.

Conclusion influencing factors mobility hub usage

This section has shown that factors related to the user perception and acceptance of mobility hub are:

- Proximity to mobility hub
- Costs for using the shared vehicles at the mobility hub
- Accessibility of mobility hub
- Size & variety of shared mobility offer
- Provision of electric mobility

With respect to amenities that influence the mobility hub usage, no unequivocal conclusion can be drawn, except that there is some evidence that the presence and connections to the public transport network are an important factor. Additional contextual factors that influence the chance of mobility hub usage are a high pressure on the transportation system and available resources, the presence of shared mobility in the area (not connected to the mobility hub), and favourable political and administrative conditions.

The typical user profile of a mobility hub user varies somewhat in different studies. Nevertheless, there is a slightly larger chance of a male to be a mobility hub user than a female, users are generally speaking young, highly educated. Moreover, having a positive attitude towards shared mobility and sustainable transport modes is positively correlated with mobility hub usage. Also, low car ownership levels increase the chances of using a mobility hub.

4.1.2. Mobility hub effects

This section provides an overview of existing mobility hubs' (potential) contribution to the policy goals. The four categories of policy goals are: improvement of public space, sustainable and liveable environment, reduction of (private) car usage and ownership, and improvement of accessibility (see section 3.5).

Environmental effects

Only Pfertner (2017) explicitly calculated the effects of mobility stations on the total amount of emissions reduced. He states that emissions are reduced because of two reasons:

- A lower CO_2-emission per vehicle kilometre due to smaller and more efficient vehicles in the carsharing fleet compared to the average private car
- Lower car dependency and reduced private vehicle kilometres because of (more) attractive alternatives

However, as carsharing also causes additional emissions from trips that previously have been made with lower-emission modes, one could subtract these additional emissions from the benefits.

Based on several assumptions and formulas, there is estimated that the mobility stations in Würzburg (combined with the extension of a carsharing system) lead to 650 tons of CO_2 emissions saved in one year. To give an impression of the relative impact of mobility stations, the saved CO_2 emissions are approximately 1% of all local transportation emissions in the city (Pfertner, 2017).

Mode choice, car usage and VKT effects

Van Rooij (2020)'s survey on Hely hub users in Delft, Amsterdam and the Hague found that the Hely hubs do not decrease the number of car trips, as bike and train trips are replaced with car trips, and previously made trips with the private car are now replaced with cars via the hub. At the Würzburg mobility stations, 50% of all carsharing trips replaced a public transport trip, and 23% substituted a trip by private car (Pfertner, 2017). Heller (2016) has conducted a survey for Offenburg mobility station users and posed the following question: "If the bike sharing / carsharing offer would not exist, what means of transport would you have taken instead?". This leads to the responses as shown in Figure 20. Bike sharing replaced 64% of walking trips, 27% private bike, 18% private car. Carsharing most often replaces trips by public transport (40%), 26% private car, 25% private bike. The category *other* is when respondents indicated that they would not have made the trip without carsharing available. This thus implies that carsharing generates more car trips (Heller, 2016).

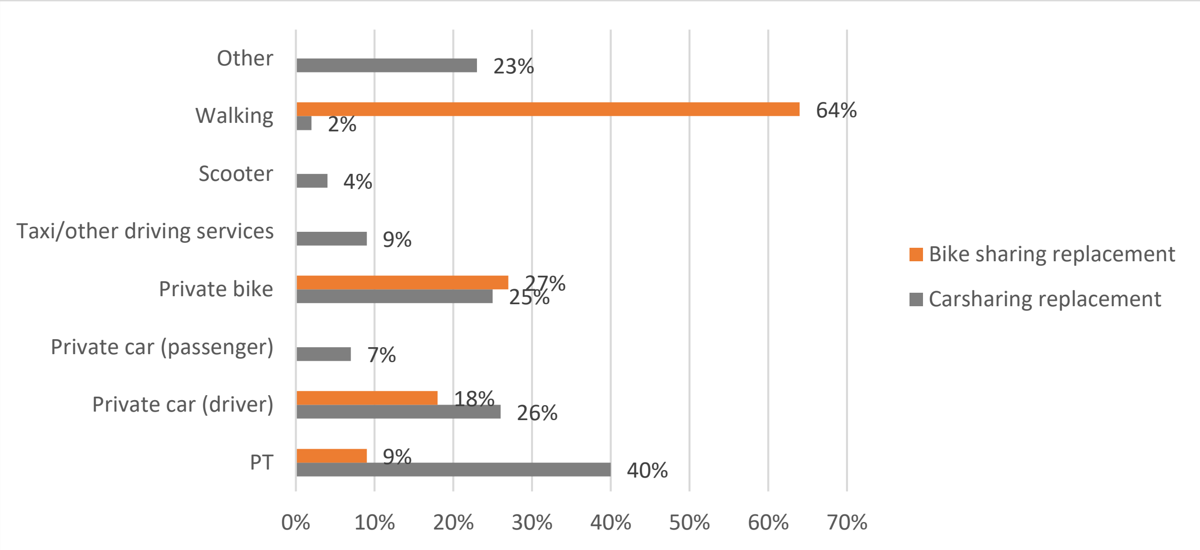


Figure 20: Mode of transport used instead of carsharing/bike sharing in Offenburg mobility stations (Heller, 2016). *Note: multiple responses possible: sum of responses >100%.*

Using mobility hubs contributes to more multimodal travel behaviour. Bike and carsharing users started to use public transport more often since they also use the mobility station. This is also visible in the statistics when people are asked which mode of transport they would have used for their last trip instead of bike or carsharing, 70% of the users then states that they would have used public transport (Miramontes et al., 2017)

As a consequence of reduced car ownership due to the introduction of the mobility station, a reduction of 8.9% VKT is estimated (Alarcos Andreu, 2017). No significant changes are found in the modal split before and after the introduction of the mobility station. However, one could say that it has influenced the travel behaviour of the residents as the number of bike and carsharing registered members increased, as well as the number of public transport monthly tickets (Alarcos Andreu, 2017).

Car ownership impact

In his master thesis, Claasen (2019) has researched the potential effects of mobility hubs and based on a stated choice experiment in The Hague. With respect to car sharing and car ownership, he concluded that a mobility hub has the potential to reduce the household car ownership (including residents who already had plans to relinquish their least used before the implementation of the mobility hub) with 19.3 % in neighbourhoods in the city of The Hague and 13.2% in Ypenburg and Leidschenveen. This effect is a reduction of 13.6% in The Hague and 8.6% in Ypenburg and Leidschenveen (when residents that are already planning to relinquish their car are not taken into account). Although this might sound promising, most residents still prefer their private car instead of the shared vehicle options in the mobility hubs. So probably a mix of measures in combination with the mobility hubs would be most effective (Claasen, 2019).

With respect to private car intentions of Hely users, Knippenberg (2019) concludes that 50% of the respondents consider having fewer cars in their households. Hely is mainly seen as a replacement for the households' second car. 33% of the hub users and 6% of the non-users sold or did not buy an (extra) car in Van Rooij (2020)'s survey. Another 33% of the users did not have a car before the hub was opened, and using the hub did not change their (non) car ownership.

The evaluation of a private mobility station for residents of a certain neighbourhood in Munich showed that car ownership has decreased by 16.6% compared to before (2014) and after (2017) the implementation of the mobility station. The average number of cars per household decreased from 0.85 to 0.55. 33% of the household indicated that the new mobility has strongly or partially influenced them offers in the area in their decision to sell their cars, these households are also users of the mobility station. Therefore, it can be stated that the mobility station directly impacts the sale of cars. When converting this to the mobility offer, 3.6 cars substituted one car at the mobility station (Alarcos Andreu, 2017).

Discussion

Based on the abovementioned results, it can be said that mobility hubs contribute to more sustainable travel behaviour, reduced VKT and a reduction in car ownership. However, the decision to relinquish or acquire a car is a long-term decision and is influenced by various factors that are not fully captured in these studies. The results only reflect a 'snapshot' of reality. The longer-term effects are not investigated as the mobility hubs are relatively new, and executed studies are still focused on the early adopters. Therefore, the findings in this chapter should rather be seen as the potential impacts of mobility hubs.

Furthermore, it seems that in the previous studies, limited attention is paid to public space and accessibility as one of the main objectives. These subjects are often implicitly related to car usage and ownership or multimodality.

4.1.3. Conclusion influencing factors and effects mobility hubs

Table 7 summarises the research findings from this section. The mobility hub introduction and usage leads to lower car ownership and more multimodal travel behaviour. By providing various modalities in the mobility hub, the vehicle kilometres travelled decrease, which is again related to lower emissions. On the other hand, carsharing leads to additional car trips. Trips that would not have been made with a car is carsharing services were not available.

Table 7: Summary of mobility hub factors and effects with positive or negative impacts. (For legend see p.48)

Effect	Factor	Expected impacts (factor → effect)	References
Emissions	Smaller & efficient shared cars	-	(Pfertner, 2017)
	VKT	+	
VKT	Additional trips	+	
	Car ownership	+	(Alarcos Andreu, 2017)
	Offer of alternative modes	-	(Heller, 2016; Pfertner, 2017; van Rooij, 2020)
Additional car trips	Carsharing usage	+	
Multimodal travel behaviour	Mobility hub usage	+	(Miramontes et al., 2017)
Car ownership		-	(Knippenberg, 2019)
	Mobility hub introduction	-	(Alarcos Andreu, 2017; Claasen, 2019)
Modal split change		0	(Alarcos Andreu, 2017)

4.2. Shared mobility literature

As explained above, the insights gained from literature on mobility hubs will be supplemented in this section with literature on shared mobility in general. This section discusses the effects of the introduced shared modes (section 3.2). Based on this analysis, an attempt is made to estimate the effects of a mobility hub and the factors that influence the effect, research question 2. The main potential impact of shared mobility systems can be roughly categorised in transportation, environmental, land use and social effects (Shaheen & Cohen, 2013). Roukouni & Correia (2020) have identified the current main research themes in the literature on the impacts of shared mobility, see Figure 21. In line with the policy goals in section 3.5, this section focuses on the impacts on the environment, built environment and travel behaviour (see orange part of Figure 21). While the figure might imply that these research areas (the ovals) are very different and stand-alone, they are interrelated, and this will be captured in the causal loop diagram.

Investigating the impact of shared mobility on the environment is done by various studies that have looked into the impact of shared mobility on CO_2/greenhouse gas (GHG) emissions, energy consumption, air quality, and noise pollution. Main research topics within the impact of shared mobility on travel behaviour are modal shifts impacts, the role of shared mobility in first- and last-mile connectivity of public transport, impact on vehicle ownership, impacts of vehicle kilometres travelled and finally, the impact of potential synergies of shared mobility with the promotion of active and multi-modal transport. With respect to the built environment, key research areas are parking supply, land use and urban aesthetics (Roukouni & Correia, 2020). The focus of the studies used in this section lies on preferably Dutch studies, or comparable countries, B2C business models and systems that are station-based (expect shared scooters) because those are the concepts that could be applied to a mobility hub.

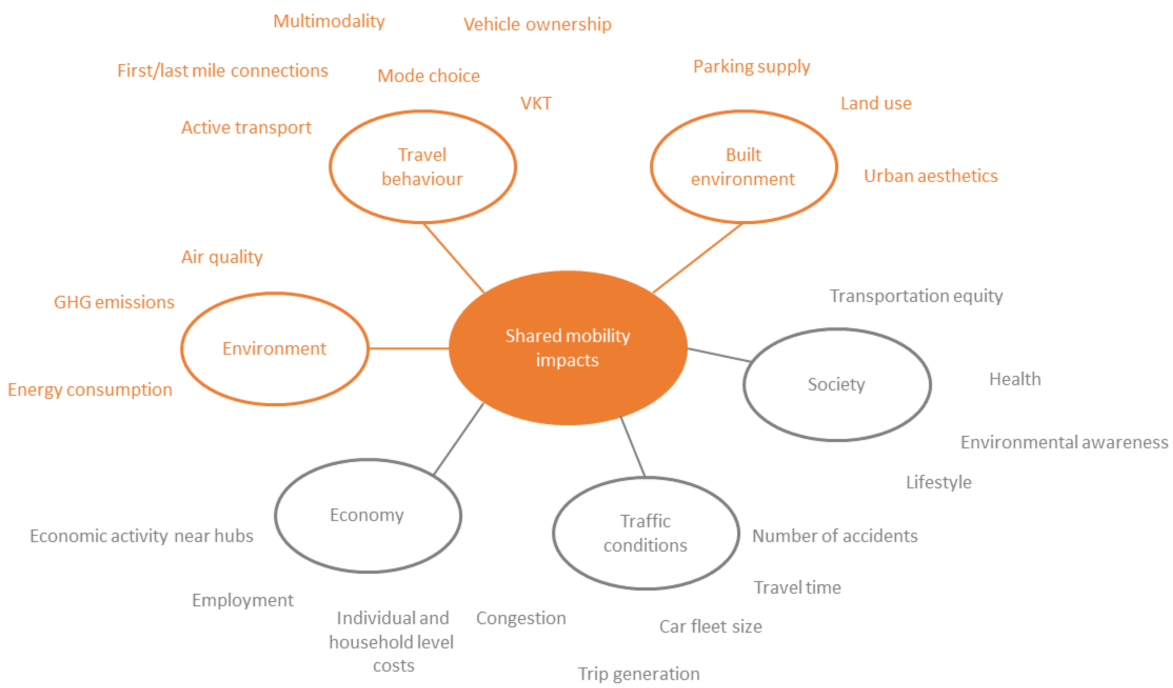


Figure 21: Research areas of impacts of shared mobility (Roukouni & Correia, 2020). The focus of research is on orange areas.

4.2.1. Carsharing influencing factors and effects

In early 2020, there were approximately 64 000 shared cars and 730 000 car sharing users in the Netherlands. Interesting to note is that 83% of the vehicles are P2P car sharing. Of the none P2P vehicles, 27.7% (3130) of the total carsharing fleet in the Netherlands are roundtrip systems. Moreover, the fastest car-sharing supply growth is in the four largest cities (Amsterdam, Rotterdam, the Hague, Utrecht) (CROW, 2020).

Many researches have analysed the environmental and travel behaviour impact of (station-based) carsharing. However, the magnitude of the impacts is not always consistent due to different methodological setups (H. Becker et al., 2018; Jung & Koo, 2018; Shaheen et al., 2019). Nevertheless, academic and non-academic studies generally agree upon the following impacts of carsharing (Shaheen et al., 2019):

- Reduced private vehicle ownership: sold, delayed or foregone vehicle purchases
- Reduced vehicle kilometres travelled (VKT)
- Reduced fuel consumption and GHG emissions
- Increased use of some alternative transportation modes
- Increased access and mobility for car-free households

In the following paragraphs these impacts, and their influencing factors are discussed, followed by a conclusion in which the findings are summarised in a table.

Replacement of private car trips

A stated choice experiment with a sample of 1000 Dutch respondents and subsequently a latent class analysis found that 40% of the sample indicated that they are willing to use carsharing to replace (some of) their private car trips when carsharing would become available for them nearby (Liao et al., 2020). The authors identified the attributes and impacts and concluded that the type of shared car, registration costs and average access time to the shared vehicle are significant predictors of private trip replacements. Moreover, attributes of their private car such as the fuel costs and the parking distance positively impact the private trip replacement potential. Environmental considerations have not been found to be an influencing factor in consideration of private car trip replacements by carsharing.

Private car ownership impacts

In 2015, research is done by the 'Planbureau voor de Leefomgeving' in which they studied the mobility and emission effects of car sharing in the Netherlands (Nijland & van Meerkerk, 2017). Based on a survey of 363 carsharing users (20% P2P, 50% B2C, 30% both), the authors found that car ownership per household decreased by 19% on average. Furthermore, 37% of respondents would have bought another car if they would not have started car sharing. Also, in the group of respondents that did not own a car before, 8% did not buy a car due to carsharing (Nijland & van Meerkerk, 2017).

The beforementioned research of Liao et al. (2020) also explored carsharing system attributes on private car ownership reduction. It seemed that 20% of the sample are likely to dispose of a current car or give up the intention to purchase a car when carsharing come available nearby. Similar to the attributes of car trip replacements, the access time, monthly membership costs and car availability of the carsharing system is expected to have a significant impact, next to the variables with respect to the current (or planned) private car. Although people with higher education levels and income tend to be more likely to join and use carsharing, they are also less likely to dispose of their own car. People that are more attached to their private car or own a relatively expensive car are less likely to forego car ownership. Finally, the fuel type of the shared vehicles and the environmentally friendly image of carsharing seem to barely impact the decision to dispose a private car. Finally, with respect to the relation between trip replacement and car ownership, the decision to forego car ownership does not solely depend on the consideration of how many current trips by the private vehicle can be replaced by carsharing, other factors override this decision (Liao et al., 2020).

Another study amongst carsharing users in Bremen, Germany, showed that car ownership in the group of carsharing users is three times lower than in the control group. Where 80% of the users in the control group have a private car available to them, this is only 20% in the group of carsharing users (Schreier et al., 2018). Moreover, they calculated that in Bremen, one shared vehicle replaces 16 privately owned vehicles. This substitution rate is higher than in other studies, where the estimate vary between 2.5 and 13 vehicles replaced per shared car (Liao et al., 2020).

Vehicle kilometres travelled impact

The paper of Wu et al. (2020) provides a comprehensive overview of the factors associated with roundtrip carsharing frequency and the impact of driving mileage through literature research and analysis of data from Britain's Annual Survey of carsharing users. They state that previous studies have shown that, on average carsharing users experience a decrease in vehicle kilometres travelled (VKT), albeit a large variation between users. However, they also discuss that much of the VKT-impacts literature are relatively early studies. Consistently with previous studies, they concluded that there is indeed a reduction in annual VKT that preliminary arises from a small proportion of the users decreasing their VKT by a large amount, and a larger proportion increasing their VKT by a relatively small amount (H. Becker et al., 2017; Wu et al., 2020). Furthermore, their regression analysis indicated that the proximity of carsharing vehicles to users is associated with larger VKT reductions. And the trip purpose that is most significantly associated with a decrease in VKT is the use of carsharing to visit friends/relatives (Wu et al., 2020).

The carsharing survey in Bremen found that kilometres travelled by a 'carsharing household' are more than 50% lower than in an average household in Bremen (Schreier et al., 2018).

Regarding the impact of carsharing and private car use in the study of Nijland & van Meerkerk (2017), people who disposed of their private cars drove fewer kilometres. On the other hand, some trips by shared car would not have been travelled by car if the respondents would not have a shared car available. All in all, car sharers drive around 15%-20% fewer car kilometres than before they started car sharing.

Emission impacts

In general, a reduced environmental impact due to carsharing is caused by one or more of the following factors (Schreier et al., 2018):

- Fewer vehicles are required, and therefore lower pollution from production and energy generation is required
- Fewer kilometres driven
- New vehicle technologies that pollute less due to the low average age of fleet or high share of electric vehicles

Jung & Koo (2018) have examined the environmental impacts of roundtrip carsharing services by investigating the impact of a modal shift and car ownership on GHG emissions. They conducted this analysis by a stated choice survey distributed in Korea. Their results imply that carsharing may not be as environmentally friendly as expected because the GHG emissions resulting from the shift away from public transport or private vehicles to carsharing services outweigh the GHG reduction of unpurchased vehicles. This research is, however, based on the assumption that all carsharing vehicles are conventional vehicles, which is not fully representative for the carsharing fleet in the Netherlands. The authors state that a larger proportion of electric vehicles in the carsharing fleet would result in more positive environmental effects.

The effect of carsharing, in the Netherlands, on CO_2 emission is quantified as a reduction between 13% and 18% related to car ownership and car use (Nijland & van Meerkerk, 2017). However, this research did not, at least explicitly, account for the relatively high share of electric vehicles in the total vehicle fleet in the Netherlands. As of spring 2020, 8% of the shared vehicles were electric, which is approximately three times more often than in the average vehicle fleet in the Netherlands (CROW, 2020). This demonstrates that the research of Nijland & van Meerkerk (2017) gives a good indication but might not be fully representative (anymore).

Research on an electric carsharing scheme in Brazil showed that using a systems dynamics methodology, increasing the e-carsharing fleet leads to a reduction in private cars and increases the total electric vehicle fleet. The authors argue that e-carsharing users can experiment with the technology and change their opinions about the future purchase of an electric vehicle. Next to a modal shift from the use of private cars to carsharing and other sustainable modes, as electric vehicles do not emit any GHGs, a larger share of electric vehicles in the total car fleet is beneficial. Moreover, electric vehicles require less need for car parts and thus fewer emissions caused in the manufacturing process (Luna et al., 2020).

Carsharing adopter characteristics and influencing factors

The variables that influence the likelihood for a person to be a carsharing adopter are partly in line with the early adopter description from Rogers (2003). High level of education, a high likelihood of living in a car-free household, having a positive attitude towards the environment, and public transport have been shown to significantly influence the likelihood of a person to be a carsharing adopter (Münzel et al., 2019). While some studies indicate that being male and having a high income are also important attributes, Münzel et al. (2019) do not confirm this.

While some of the earlier studies of carsharing suggested that environmental aspects are one of the most important motivations to start carsharing, over time, financial and convenience motives have evolved to be the primary reasons. Furthermore, a significant change in personal circumstances has also shown to be a pull factor to join carsharing. Interestingly, Münzel et al. (2019) found no significant influence between living in one of the four largest cities in the Netherlands and the likelihood of adopting carsharing. This indicated that carsharing is not only a large city, high population density phenomenon.

Schreier et al. (2018)'s survey identified carsharing priorities and found 'straightforward booking', 'availability of vehicles', 'proximity of nearest station', 'easy-to-use vehicles', 'accommodating arrangement in case of damages etc.' and '24-hour availability of the provider by telephone' factors of high relevance or decisive importance.

Conclusion influencing factors and effects carsharing

Table 8 summarises the research findings from the previous paragraphs. The variables in Table 8 to Table 12 are formulated in a neutral way, meaning not using the words 'replacement', 'reduction' etc. A negative (-) expected impact implies that when the defined variable in the factor column increases, the variable in the effect column decreases. A positive sign (+) thus means a positive correlation; both factors increase. In the rows with a +/- sign, the impact is unknown depending on further elaboration of the factor (i.e. there is a causal relation between the type of shared car and an increased/reduced private car usage, but one cannot say when the 'type of car' increases so does 'private car usage'). Finally, some variables are depicted with a 0. This says that there is no causal relation found based on the current research.

Table 8: Summary of carsharing factors and effects with positive or negative impacts. (For legend see p.48)

Effect	Factor	Expected impacts (factor → effect)	References
Private car usage	Type of shared car	+/-	(Liao et al., 2020)
	Carsharing membership costs	+	
	Average access time to shared car	+	
	Private car fuel costs	-	
	Parking distance private car	-	
	Environmental considerations	0	
Private car ownership	Carsharing usage	-	(Liao et al., 2020; Nijland & van Meerkerk, 2017; Schreier et al., 2018)
	Carsharing available nearby	-	
	Average access time to shared car	-	(Liao et al., 2020)
	Monthly membership costs	+	
	Private car variables	+/-	
	Education level	-	
	Income level	-	
	Attachment to private car	+	
	Purchase costs of private car	-	

Effect	Factor	Expected impacts (factor → effect)	References
VKT	Carsharing usage	-	(H. Becker et al., 2017; Nijland & van Meerkerk, 2017; Schreier et al., 2018; Wu et al., 2020)
	Private car ownership	+	(Nijland & van Meerkerk, 2017)
	Average access time to shared car	+	(Wu et al., 2020)
	Trip purpose: visit friends/family	-	
(GHG/CO_2) emissions	Total vehicle fleet size	+	(Schreier et al., 2018)
	VKT	+	
	Average carsharing fleet opposed to total fleet (on average newer and cleaner, more EV's)	-	(Luna et al., 2020; Schreier et al., 2018)
	Larger share of EV's in total vehicle fleet	-	(Luna et al., 2020)
	Private car ownership	+	(Nijland & van Meerkerk, 2017)
	Private car usage	+	
	Additional trips because of carsharing	-	(Jung & Koo, 2018)
Experimenting and familiarizing with EV's	E-carsharing usage	+	(Luna et al., 2020)
Larger share of EV's in vehicle fleet	Experimenting and familiarizing with electric vehicles	+	
Likelihood of being carsharing user	Level of education	+	(Münzel et al., 2019)
	Likelihood of living in car-free household	+	
	Positive attitude towards environment	+	
	Positive attitude towards public transport	+	
	Income level	+/-	
	Male	+/-	
	Living in G4 NL	0	
	Convenience in booking process	+	(Schreier et al., 2018)
	Availability of shared cars	+	
	Proximity of shared cars	+	
	Convenience in use of shared cars	+	
	Support in case of damages etc.	+	
	24-hour availability of provider	+	

4.2.2. Bike sharing influencing factors and effects

Bike sharing systems are expected to contribute to a number of different objectives (Barbour et al., 2019; Ricci, 2015; Shaheen et al., 2010; Zhang & Mi, 2018):

- Reduce car trips
- Reduce CO_2 emissions and improve air quality
- Increase cycling levels and promote cycling
- Improve accessibility and support multimodal transport connections
- Ease traffic congestion and single occupancy car journeys
- Enhance image and liveability of cities
- Improve public health and increase the level of physical activity

Although bike sharing programs are not new, and exist for already 50 years, their popularity is rising rapidly now that dockless bikes are common. Because of the benefits associated with bike sharing and the wish for sustainable urban design by policymakers, bike sharing is increasingly important in the field of urban planning. In general, bike sharing is perceived to have the potential to decrease the car-dependency and is viewed as an especially suitable mode for the first and last-mile transport (Ricci, 2015).

Modal shift bike sharing

Previous studies have shown that only a minority of car trips are being replaced by bike sharing. Percentages of modal shift vary from 0.3%-20% (Ma et al., 2020). Specifically based on European examples, Ricci (2015) summarises the findings from a variety of user surveys to a modal shift between 2% and 9.6%. The impact of reduced car trips is relatively small, as the vast majority of trips made by shared bikes are a substitution of trips with other sustainable transport modes (walking, private bike, public transport).

Applied to the Netherlands, a study in 2017 on the effects of Dutch bike sharing systems found that 17% of the 'OV-fiets' (bike sharing system owned and operated by the Dutch railways and located at train stations) users stated that they sometimes use a combination of train and 'OV-fiets' instead of a trip that would have been previously made with the car (Rijkswaterstaat, n.d.). This is rather optimistic as Ma et al. (2020) did not found a modal shift change from private car due to the OV-fiets in their case study in Delft. Van Gerrevink (2019) has researched the modal shift of dockless bike sharing service, Mobike in Delft. The user survey has shown that almost everyone (97%), when Mobike would not be available, would have travelled with other sustainable transport modes such as walking, private bicycle, OV-fiets, or public transport. While based on a slightly different question, Ma et al. (2020)'s findings on the Mobikes in Delft are similar. Mobike users decreased their usage of a private car, bus and tram, private bicycles, and walking after the introduction of Mobike. However, also some users stated that they did increase their public transport usage. This is explainable because the Mobikes are used as first- and last-mile transport.

Van Marsbergen (2019) researched the combined use of shared bicycles and public transport. As a case study, the HTM-fiets bike sharing program in The Hague is investigated. As in line with the other studies mentioned, the HTM-fiets mostly replaces other sustainable modes (see Figure 22 for the modal shift). Of which the tram substitution (37%) is the most significant. 10% of the respondents would have used the car or taxi/uber if the HTM-fiets was not available.

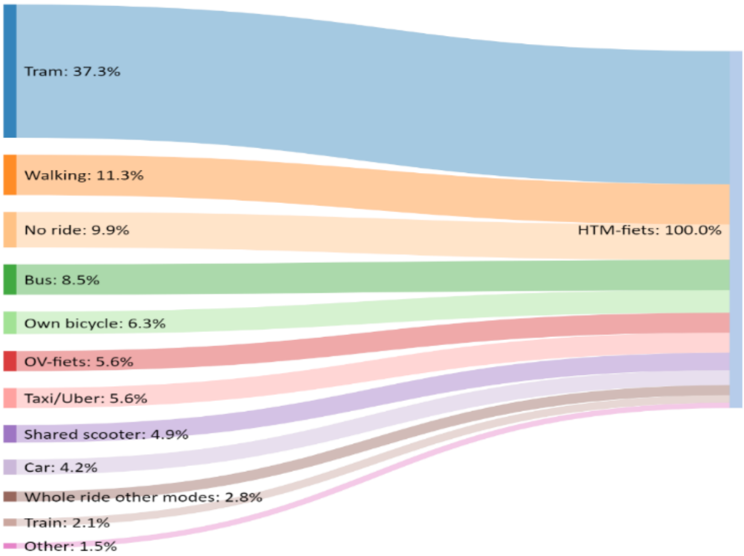


Figure 22: Transport mode used if HTM-fiets was unavailable (Van Marsbergen, 2020)

Socio-demographic factors bike sharing

Van Marsbergen (2019) also conducted a literature review of factors that influence the usage of shared bicycles and/or the usage of the shared bicycle in combination with public transport. However, not all factors identified are relevant for this study, as they are not always applicable to the Dutch situation or very much focused on the bicycle-transit combination. Van Marsbergen looked into various socio-demographic that could influence the shared bike usage. However, she argues that there are some contradicting results, and many aspects are also dependent on the country and culture. For example, some studies have suggested that men are more likely to use shared bikes than women (Bachand-Marleau et al., 2013; Ma et al., 2020). However, this is especially the case in countries where cycling is not so common. In countries with higher cycling levels, this balance between men and women is much more equal (Heinen et al., 2010). The same goes for private bicycle ownership, Bachand-Marleau et al. (2013) state that bicycle ownership decreases the likelihood of becoming and bike sharing member and also negatively impacts the bike sharing usage frequency. However, in the Netherlands, the average bicycle ownership is very high.

Trip factors bike sharing

Eren & Uz (2020) have done a literature review on factors that affect trip demand in researching the effectiveness of station-based bike sharing programs. The factors are divided in several categories; firstly, adverse weather conditions such as rain, strong winds, temperatures lower than 10°C or higher than 30°C, and humidity reduce bike sharing demand. The most favourable conditions are dry weather with temperatures between 20-30°C. Secondly, important built environment and land use factors are the bike infrastructure in general. The length of bicycle paths and whether they are separated has a strong positive causal relation. Moreover, an attractive built environment with mixed land use and green spaces stimulates cycling. A barrier to conventional bike sharing is hilly areas, electric bikes, on the other hand, could provide a solution to this. Thirdly, they looked at public transportation impact factors and found that the presence and number of bus, metro and train stops are positively correlated with bike sharing demand.

Trip distance is negatively related to the use of bike sharing (Campbell et al., 2016). In general, the bicycle is most popular for distances between one and five kilometres (Joeri van Mil, 2017). The trip purpose potentially also impacts the shared bike usage. The Mobike study in Delft has shown two main user groups, the ones that use a Mobike for their daily commute and therefore have a high usage frequency. The second group are the inhabitants of Delft, of which are a large share of users are students. They generally do own a private bike and thus use the shared bikes occasionally (van Gerrevink, 2019).

Conclusion influencing factors and effects bike sharing

Table 9 summarises the abovementioned findings of the factors that influence the usage and effects of bike sharing.

Table 9: Summary of bike sharing factors and effects with positive or negative impacts. (For legend see p.48)

Effect	Factor	Expected impacts (factor → effect)	References
Private car usage	Usage of bike sharing system	-	(Barbour et al., 2019; Ricci, 2015; Shaheen et al., 2010; Zhang & Mi, 2018)
(GHG/CO_2) emissions		-	
Cycling levels		+	
Traffic congestion		-	
Public health & physical activity		+	
Usage of bike sharing system	Adverse weather conditions: rain, strong wind	-	(Campbell et al., 2016; Eren & Uz, 2020; Faghih-Imani et al., 2014; Van Marsbergen, 2020)
	Temperatures between 10-30°C	+	
	Humidity	-	
	Sunny	+	
	Bicycle path length	+	
	Percentage separated pathway	+	
	Mixed land use and green space	+	
	Hilly areas	-	
	Trip distance	-	(Campbell et al., 2016)
	Socio-demographic factors (age, gender, education level, bicycle ownership, level of cycling, level of PT use)	+/-	(Bachand-Marleau et al., 2013; Campbell et al., 2016; Faghih-Imani et al., 2014; Fishman, 2016; Fishman et al., 2013; Ma et al., 2020; J. van Mil et al., 2018; Van Marsbergen, 2020)

Shared e-bike

Electric bicycles (e-bikes) are seen as a relatively new high potential solution for reducing automotive vehicle kilometres travelled and reduced emissions. As e-bikes encourage users to cycle faster and longer distances with less physical effort on a conventional bicycle, there are high hopes that e-bikes can play a role in contributing to better air quality, less air and noise pollution and reduction of traffic congestion (McQueen et al., 2020; Sun et al., 2020). There are currently few studies about e-bike share (He et al., 2019; Liao & Correia, 2020), which makes it hard to assign an exact impact. However, studies on private e-bikes have shown a high substitution rate of private car trips and prove that e-bikes have a stronger effect than traditional bike sharing on substituting private car trips (Bourne et al., 2020; Cairns et al., 2017; de Kruijf et al., 2018). Moreover, the implementation of shared e-bike systems can contribute to the share of (private) e-bikes as a sustainable transport mode in the long term. Shared e-bikes systems have been shown to contribute to an increased awareness of e-bikes and a modest increase in people that consider a (private) e-bike for their commute (Handy & Fitch, 2020). Table 10 summarises the abovementioned findings.

Table 10: Summary of e-bike sharing factors and effects with positive or negative impacts. (For legend see p.48)

Effect	Factor	Expected impacts (factor → effect)	References
Private car usage	Private e-bike ownership and use	-	(Bourne et al., 2020; Cairns et al., 2017; de Kruijf et al., 2018)
Air quality	E-bike sharing trips	-	(McQueen et al., 2020; Sun et al., 2020)
Air and noise pollution		-	
Traffic congestion		-	
Awareness of e-bikes	Presence and usage of e-bike sharing system	+	(Handy & Fitch, 2020)
Private e-bike ownership and use		+	

Shared e-cargo bike

Empirical research among almost 1000 users of 30 cargo bike sharing operators in Germany and Austria found that cargo bike sharing can contribute to the reduction of private car use, and the associated negative environmental impacts. 46% of the respondents indicated that they would have used the car in the absence of cargo bike sharing services for their trip (S. Becker & Rudolf, 2018). Although it must be said that 25% of the people that would have travelled by car would use carsharing (S. Becker & Rudolf, 2018), these figures show the significant environmental potential for cargo bike sharing. Dorner & Berger (2020) adds on to that, that an indirect effect of cargo bike sharing is that it also has the potential to change mobility behaviour as it makes (first-time) users consider the use of cargo bikes for future trips and might even stimulate them to buy one for regular use in future. Table 11 summarises the abovementioned findings.

Table 11: Summary of cargo-bike sharing factors and effects with positive or negative impacts. (For legend see p.48)

Effect	Factor	Expected impacts (factor → effect)	References
Private car usage	Usage of cargo bike sharing system	-	(S. Becker & Rudolf, 2018)
(GHG/CO_2) emissions		-	
Private cargo bike ownership and use		+	(Dorner & Berger, 2020)

4.2.3. Scooter sharing effects

Micro-mobility, powered two-wheelers, is an innovative urban transport solution for short-distance travel options and therefore mainly aimed to improve access to public transport (last- and first mile) and replace short car trips (Abduljabbar et al., 2021; Holm Møller et al., 2020). While the shared scooters, in theory, have high environmental potential, "previous studies on e-scooters in shared use have shown that the environmental impact of e-scooters taking into account their entire lifecycle is significantly affected by their short lifetime" (Severengiz et al., 2021, p. 181).

Moped scooter sharing

An online survey about moped sharing disseminated in different Spanish cities suggests that moped sharing can partially substitute private car trips and other less environmentally friendly modes. On the other side, for part of the trips, moped sharing is also complementary for sustainable options. Nevertheless, feeling concerned about environmental issues does increase the probability of someone being a frequent moped sharing user. Two main reasons for people to use a shared moped for their urban trip are: *easy to park the vehicle* and *provision of a flexible option to drive to the city*. This indicates that moped sharing could represent an attractive mobility alternative in car-restrictive city centres (Aguilera-García et al., 2020).

Stand-up e-scooter sharing

E-scooters are seen as relatively effortless forms of micro-mobility with the potential to be used in addition to public transport or to be an alternative for car trips. E-scooters are perceived as more effortless than other modes because they enable to travel in more formal office clothes, narrow manoeuvring is easy, it saves travel time and money, and driving an e-scooter is playful (Christoforou et al., 2021; Tuncer & Brown, 2020). However, Alberts (2021) states that e-scooter users are expected to switch mostly from active travel modes. A small shift from public transport to the shared e-scooter is expected, and only a minor shift from the car towards the e-scooter is anticipated.

A study on different shared micro-mobility providers in Zurich (Switzerland) determined several fundamental factors in mode choice. They find that there is a strong relationship between fleet density and usage. However, also a "plateau effect", when the fleet density increases above this threshold, there is marginal utility gains (Reck et al., 2021). Besides, docked modes (bike and e-bike sharing) are preferred for commuting and are therefore used in rush hours. E-scooters, on the other side, are more often used outside rush hours (Reck et al., 2021). With respect to the replacement of car trips, e-scooters are a strong alternative for short trips between 800m and 3.2 km in car-constrained environments (Smith & Schwieterman, 2018).

Environmental burdens of e-scooters are primarily related to lifecycle considerations of materials used in the production, manufacturing process, re-distribution (in free-floating system) (Hollingsworth et al., 2019). When looking at the life cycle impacts, e-scooters may not necessarily reduce environmental impact. The precise life cycle impacts of e-scooters largely depend on their substitution of less sustainable transport modes and interventions to optimise performance and distribution impacts (Hollingsworth et al., 2019; Severengiz et al., 2021).

Moreau et al. (2020) has quantified the environmental impacts of shared dockless standing e-scooter use in Brussel and found that in the current situation, a shared e-scooter causes 131 g CO_2-eq/passenger-kilometre in a life cycle, opposed to 110 g CO_2-eq/passenger-kilometre caused by the transport mode that has been replaced by the shared e-scooter. This calculation is based on several assumptions and other studies, such as a user survey of e-scooter users in Brussels. This study found that 29.2% of the trips by e-scooter replace public transport, 26.7% car, and another 41.8% replace walking and cycling trips (Moreau et al., 2020).

The average e-scooter user is more likely to be men than women, young (between 18 and 35 years old) and highly educated (Alberts, 2021; Christoforou et al., 2021; Laa & Leth, 2020). When the e-scooters are available for a while, also older age groups are starting to use the e-scooters (Alberts, 2021). Table 12 summarises the abovementioned findings.

Table 12: Summary of scooter sharing factors and effects with positive or negative impacts. (For legend see p.48)

Effect	Factor	Expected impacts (factor → effect)	References
Private car usage	Usage of e-scooter sharing system	-/+	(Smith & Schwieterman, 2018)
CO2-eq/passenger-kilometre		+	(Hollingsworth et al., 2019; Moreau et al., 2020; Severengiz et al., 2021)
Usage of e-scooter sharing system	Trip length between 0.8-3.2 km	+	(Smith & Schwieterman, 2018)
	Fleet density	+[4]	(Reck et al., 2021)
	Outside of rush hours	+	

4.2.4. MaaS

Mobility as a Service (MaaS) concept is a digital platform that aims to combine different transport modes to ensure that the user can make seamless trips over one interface (Utriainen & Pöllänen, 2018). This means that the user can search, compare, (reserve) and pay for a mobility service through one smartphone application. The main idea of MaaS is to (digitally) bundle mobility modes and hereby enable a shift from ownership-based to an access-based transport system. By providing this seamless travel, MaaS has the potential to contribute towards to goals of multimodal systems and substituting private vehicles with alternative modes (Jittrapirom et al., 2017). The core characteristics of MaaS are the integration of transport modes, a tariff option, one platform, multiple actors, use of technologies, demand orientation, registration requirements, personalisation and customisation (Jittrapirom et al., 2017).

In many policy plans regarding shared mobility and mobility hubs, MaaS is seen as one of the prerequisites of a mobility hub. According to the Mobiliteitsalliantie (2019), all modes offered in the mobility hub must be integrated on a MaaS platform to be physically and virtually integrated. Therefore, MaaS and mobility hubs are closely related, and the objectives and expected benefits largely correspond. Namely reduction of emissions, private car ownership and car use, traffic congestion, providing personalised transportation solutions, and a reduction in street space for cars and parking which frees up space for other land uses (Pangbourne et al., 2020; Wong et al., 2020). No further attention is given to MaaS specifically.

4.2.5. Discussion shared mobility literature

Public space impact

Remarkable is that the literature used in this section did not explicitly mention shared mobility impacts on public space, while this is one of the important policy themes as followed from the policy document content analysis (see section 3.5.2). Though some studies mention effects on *emissions*, *traffic congestion* and *air quality*, for example, it is hypothesised that these factors are also somehow linked to the quality of public space. To confirm this relationship and enable modelling of this policy theme in the causal loop diagram, the current literature is slightly expanded to parking facilities and impact on travel behaviour.

As Christiansen et al. (2017) rightly state: "car parking policy is significant in influencing transport, since almost all car trips start and end in a parking space" (Christiansen et al., 2017, p. 198). Parking availability and the cost of parking can influence mode choice, destination choice, trip timing, car occupancy and car ownership. Although this study researched the

[4] Strongly positive relation up until 'plateau effect'

wide effects of parking facilities on travel behaviour, relevant conclusions are that not having one's own designated parking space reduces the probability of choosing the private car for a trip. Similarly, the walking distance between home and home parking also significantly reduces this probability. Besides, this is not only of influence at the start end of the trip, but also reduced parking availability at the trip end reduces the odds of driving (Christiansen et al., 2017). This demonstrates that in relation to the previously found factors, *parking availability* could be added, which negatively correlates to *parking distance private car*, which in turn negatively correlates to *private car usage and ownership*. Besides, based on the statements in the policy documents (Table 29), fewer parking spaces (i.e. lower *parking availability*) frees up public space, which could be arranged differently, improving the *quality of the public space*.

Direct and indirect impacts

Secondly, from this literature analysis follows that some researches mention that due to, for example, the usage of bike sharing system, the GHG emissions decrease. However, by making one bike sharing trip, GHG emissions do not simply vanish. Based on the authors own perception, the correct way to describe this effect is that only when a bike sharing trip replaces a trip with a less environmentally friendly mode (i.e. private car trip), emissions are decreased due to the usage of bike sharing. Therefore, the identified causal relations are reconsidered and sometimes (indirect) causal relations are adjusted accordingly before being implemented in the causal loop diagram.

4.3. Conclusion influencing factors and effects of mobility hubs

Literature on the influencing factors of usage and effects of mobility hubs is limited. Nevertheless, the existing literature has been thoroughly investigated, leading to insights into user perceptions, desired amenities, user characteristics, and several context factors. With respect to the effects of a mobility hub, some evidence has been found that mobility hub usage leads to reduced car usage and ownership, which is thus beneficial for the air quality. One of the strengths of a mobility hub is the provision of multiple modalities and facilitating transfer options. This stimulates the usage of sustainable shared modalities such as bike sharing. However, carsharing is the most popular transport mode at the mobility hub, and some researches have shown that carsharing leads to additional car trips. Trips that would not have been made with a car is carsharing services were not available, which is an undesirable effect.

In the second part of this section, the scope is broadened to station-based shared mobility in general. The shared modalities of carsharing, bike sharing and scooter sharing are explored. This has given a more in-depth insight into the usage factors of these modes and their effects. The carsharing impacts have been further quantified where possible, influencing socio-demographics have been studied, and the relation between the private car and shared car is investigated. Similarly, some socio-demographic and trip factors have been identified for bike sharing, and there is elaborated on the modal shift from bike sharing. It seems that bike sharing is often used as a replacement mode for other sustainable transport forms. Bike sharing itself is therefore not necessarily contributes to the determined policy goals.

Limited research is available for shared e-bikes and cargo bikes. Nevertheless, because of their speed (e-bikes) and convenience in carrying goods (cargo bikes), these modes have significant potential to replace private car trips and contribute to reducing GHG emissions.

Like bike sharing, scooter sharing is expected to induce a modal shift mostly from active travel modes to the e-scooter. Only a minor shift from the car towards the e-scooter is anticipated.

Due to the complexity of the system and the numerous identified factors and effects, this section is not summarisable in words. The findings have thus been structured in Table 7 Table 12. A 'summary' of this literature review is provided via the initial causal loop diagram in the following chapter. This causal loop diagram presented in the next chapter thus also answers the second research question.

Causal loop diagram construction

5. Causal loop diagram construction

The goal of this chapter is to come to a design of an initial causal loop diagram. As described in chapter 2 Methodology (and shown in Figure 23), the causal loop diagram is based on several inputs such as a conceptual framework, a Bull's eye diagram, which is drawn up to scope which factors should be in- and excluded in the CLD, and the literature review on usage factors and effects of mobility hubs as identified in chapter 4. This step of the research is related to methodology steps of 'conceptualisation' and 'specification' as described in Figure 5. The initial CLD answers the second research question: *What are the factors explaining the usage and effects of neighbourhood mobility hubs in literature?*

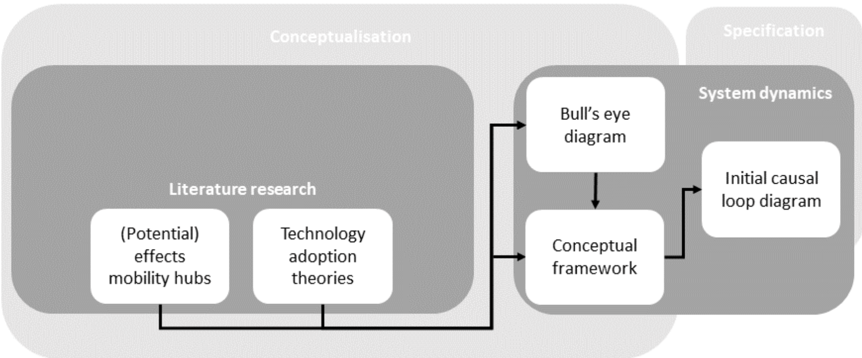


Figure 23: Structure and methodology of the chapter

5.1. Conceptual framework

This section discusses the conceptual framework on the effectiveness of a mobility hub and the identification of model boundaries shown in a Bull's eye diagram.

5.1.1. Unified theory of acceptance and use of technology model

The effects of a mobility hub depend on the adoption and the usage of the mobility hub and its shared modes. As the concept of shared mobility and mobility hubs can be classified as an innovation, there are several theories and models formulated on the adoption of innovations (Alomary & Woollard, 2015).

Venkatesh et al. (2003) has proposed the unified theory of acceptance and use of technology (UTAUT) model, which summarises eight other theories of behaviour (the theory of reasoned action (TRA), the technology acceptance model (TAM), the motivational model, the theory of planned behaviour (TPB), a combined TBP/TAM, the model of PC utilization, innovation diffusion theory (IDT), and social cognitive theory (SCT)) (Yu et al., 2020). The UTAUT model is a useful tool to "*assess the likelihood of success for new technology introductions and helps [...] understand the drivers of acceptance*" (Venkatesh et al., 2003, p. 426). The model consists of four user acceptance criteria and four moderators for behavioural intention (Kaur & Rampersad, 2018). The user acceptance criteria include *performance expectancy, effort expectancy, social influence* and *facilitating conditions*. The three moderators are *gender, age*, and *experience*.

Performance expectancy refers to the degree to which an individual believes that using the system will improve their daily series of activities. *Effort expectancy* refers to the ease of use of the system. It is based on the perception that using a system or technology should be easy or free from effort. The effect of *effort expectancy* partially interferes with *performance expectancy* (Wolf & Seebauer, 2014). *Social influence* is defined as the degree to which the individual experiences support of the environment around the user to use the new system. *Facilitating conditions* are the extent to which the users believes there is a technical and organisational infrastructure that supports the use of the system (Venkatesh et al., 2003; Yu et al., 2020).

In 2012, an update was done on the UTAUT model, which led to UTAUT2 (Venkatesh et al., 2012). This renewed model is expanded with three new constructs: *hedonic motivation*, *price value* and *habit*. Expanding the original UTAUT with motivation theory has resulted in the introduction of the *hedonic motivation* construct as a predictor of consumers' intentions to use a technology. "Hedonic motivation is defined as the fun or pleasure derived from using a technology, and it has been shown to play an important role in determining technology acceptance and use" (Venkatesh et al., 2012, p. 161). Secondly, to also focus on the consumer use context, instead of organisational use setting regarding the technology use, it followed that a *price value* construct also needed to be added. Consumers make a trade-off between the perceived benefits and the costs of using the technology (Venkatesh et al., 2012). *Price value* can be defined as the degree to which users perceive the costs of using the system is reasonable. This can either be monetary or otherwise (Jahanshahi et al., 2020). The *habit* factor refers to the extent to which users perform automatic behaviour (Venkatesh et al., 2012).

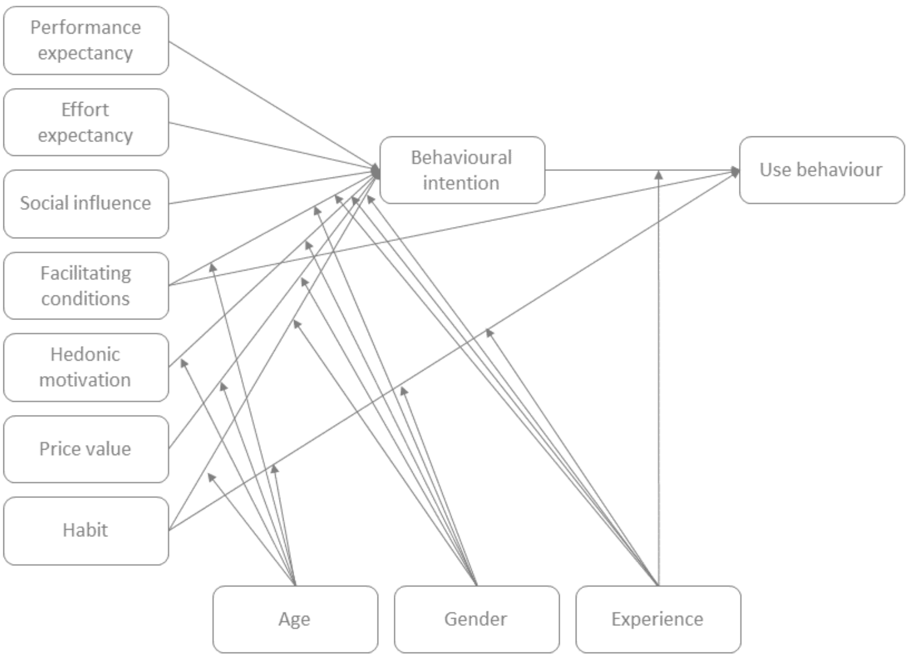


Figure 24: UTAUT2 model (Venkatesh et al., 2012)

5.1.2. Previous applications of the UTAUT model in related research

The UTAUT can, and is, used in a variety of research fields, of which the transportation field being one of them. Studies in this field mainly focus on topics ranging from automated public transport, carsharing to advanced driver assistance systems (Jahanshahi et al., 2020). This section discusses a few studies that used the UTAUT model in similar topics to mobility hubs. Attention is paid to which variables are included in these researches and findings that indicate a(n) (relative) importance.

Fleury et al. (2017), for example, researched intentions to use a corporate carsharing service in France. They have adapted the original UTAUT model and added a variable of *perceived*

environmental friendliness as an influencing factor to behavioural intention. They find that this indeed had a significant effect, albeit small. Moreover, *effort expectancy* seemed to have the strongest impact on behavioural intention to use carsharing.
Another study where the UTAUT model is applied, is an e-bike study in Austria (Wolf & Seebauer, 2014) in which the authors aimed to characterise user's profiles, e-bike use and reasons for adoption. Next to the expected influencing factors based on the UTAUT model, they also added predictors of e-bike use as mobility behaviour such as *attitude towards physical activity*, *car availability* and *distance to everyday destinations*. Based on structural equation modelling, the authors find that the UTAUT model benefited from the additional predictors on travel mode choice, and age appeared to be only a moderate predictor of use. Thirdly, (Yu et al., 2020) researched the user intentions of using a personal mobility vehicle (light-electric vehicle, LEV) via an online questionnaire based on the UTAUT model. Results show that *performance expectancy*, *effort expectancy*, *social influence* have a significant positive impact on *behavioural intention* to use LEVs. Also, their specifically added constructs of *perceived risk* and *policy measures* seemed to have a significant positive impact.

(Ye et al., 2020) studies the acceptance and intention of using MaaS with a survey in a town nearby Shanghai, China. They extended the original UTAUT model with the constructs of *perceived risk* and *individual innovation* to capture the individual's acceptance of new things in general and curiosity to try out new things. *Perceived risk* relates to the uncertainty of the outcome of using the service and the possible consequences that are related to this. As the goal of MaaS is to replace private car trips, an extra moderator is added for *family car ownership*.

Jahanshahi et al. (2020) has examined the effect of the UTAUT2 model variables on the acceptance and usage of a bike sharing scheme in Iran. Linear regression on survey data showed that *facilitating conditions,* followed by *performance expectancy*, *social influence*, *perceived safety* (added new construct to UTAUT2), are the strongest correlators to *behavioural intention* and *use behaviour*. The *price value* variable was not found to be significant for predicting *behavioural intention*. Moreover, this research did not find evidence for the support of *age, income, education,* and *experience* as moderators of the causal relation between the variables and *behavioural intention*.

5.1.3. Conceptual framework

With the knowledge of the previous paragraph and previous chapters, a UTAUT2 model is drawn up targeted for this research. Figure 25 acts as a rough framework for the design of a causal loop diagram and a check whether it fully captures the relevant variables.

The left of Figure 25 depicts the seven user acceptance criteria that influence behavioural intention. Behavioural intention is again related to user behaviour, i.e. shared mobility usage, private car usage and ownership and multimodal travel behaviour. Because this study is interested in the effects of mobility hubs, the original model is expanded with an extra arrow and box at the right side of the figure that lists the effects (identified policy goals of shared mobility and mobility hubs). Relevant moderators in this framework are age, gender, level of education, previous experience with shared mobility and private car ownership.

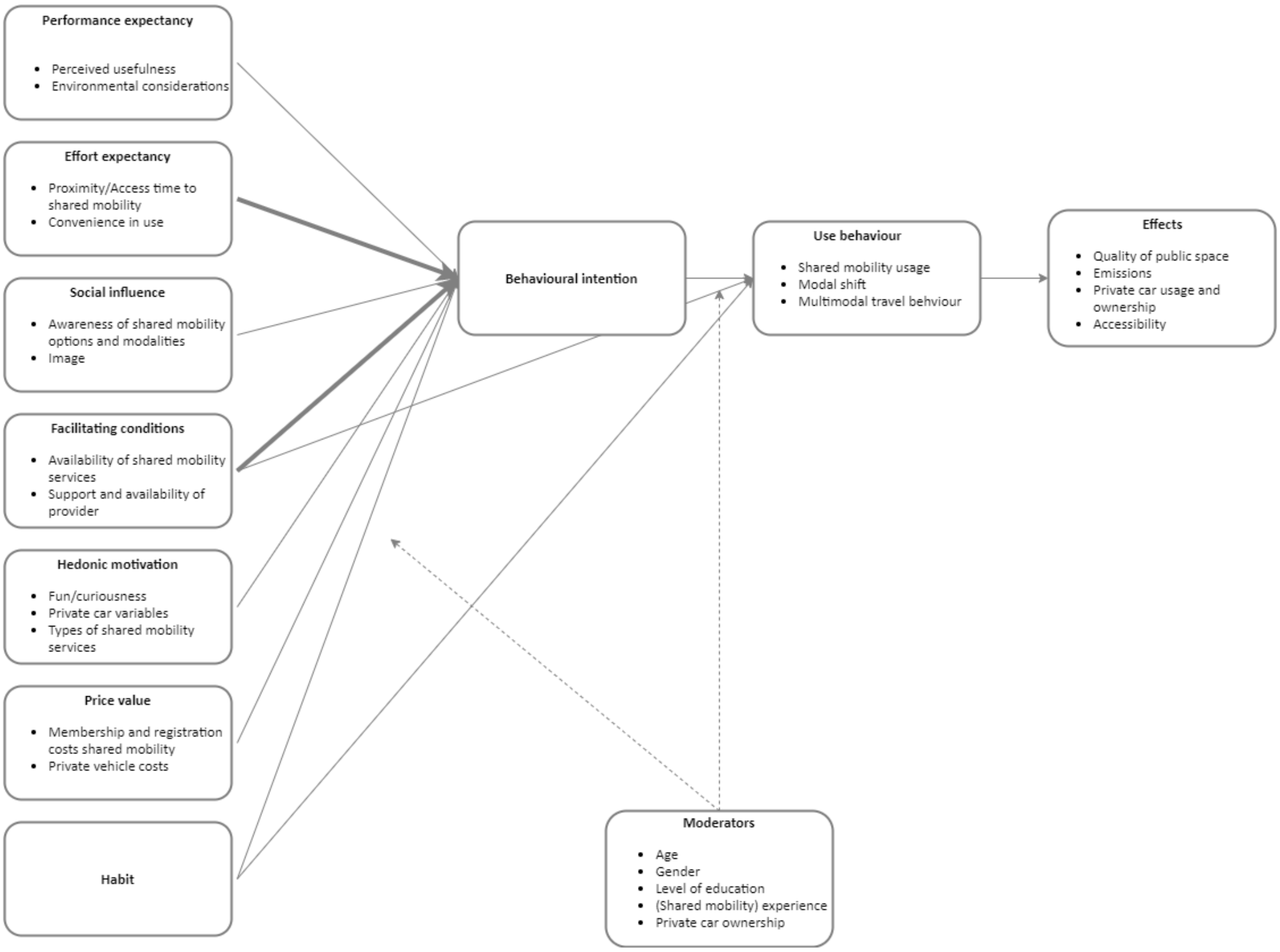


Figure 25: UTAUT2 model applied to shared mobility and mobility hubs

5.1.4. Model boundaries

A concise way to represent the model's boundaries is with a Bull's eye diagram (Figure 26). It provides a general overview of the variables modelled endogenously, exogenously and deliberately omitted elements (Pruyt, 2013). The most relevant elements are displayed in the inner circle, the *thoroughly modelled endogenous variables*. These variables will form the core of the causal loop diagram. In the next circle, the *superficially modelled endogenous variables* are displayed. These are the variables that influence the variables in the inner circle, but in a simplistic way. *Exogenous variables* are the elements that influence variables in the model, but there is no feedback. The model does not influence *exogenous variables* (Dhirasasna & Sahin, 2019).

Finally, some variables that (could potentially) influence the model are omitted due to the scope of this research, the desired level of aggregation and or the complexity. One of the exclusions that were made, are not to consider shared mobility impact regarding economy, traffic conditions and society. This is already described in the introduction of section 4.2 and Figure 21. Societal impacts include, among other things, impacts on health and transportation equity. Traffic conditions refer to variables such as congestion, traffic safety, travel time. A possible economic impact of a mobility hub could be the effect on economic activity near the hubs. However, these three categories are excluded (from the initial CLD) as they are not related to the identified policy goals for mobility hubs and therefore fall out of scope. Moreover, despite the fact that shared mobility is often used in combination with public transport it is chosen to not include public transport elements in the model as it is expected that this would considerably increase the complexity of the model and time required for literature research.

The exogenous variables are variables that are perceived as not very important but still influence the model. These are, for example, factors identified in section 4.1.1 Influencing factors mobility hub usage. The same goes for carsharing user characteristics and some private car variables (attachment, costs, etc.) that are found to influence variables placed in the more inner circles.

At the core of the circle, three of the policy goals for shared mobility and mobility hubs are placed, *private car usage*, *private car ownership* and *emissions* since they are perceived as the essential elements of the model. Although *public space* is also one of the policy themes of shared mobility (section 3.5), this is not included in the inner circle due to the absence of links between shared mobility and public space in literature (section 4.2.5). *Shared mobility usage* is placed in the category of thoroughly modelled endogenous variables as it plays a crucial link in the model between *mobility hub usage* and the ultimate effects.

The superficially modelled variables are the elements that are closely related to the thoroughly modelled endogenous variables yet with a not too complicated direct influence.

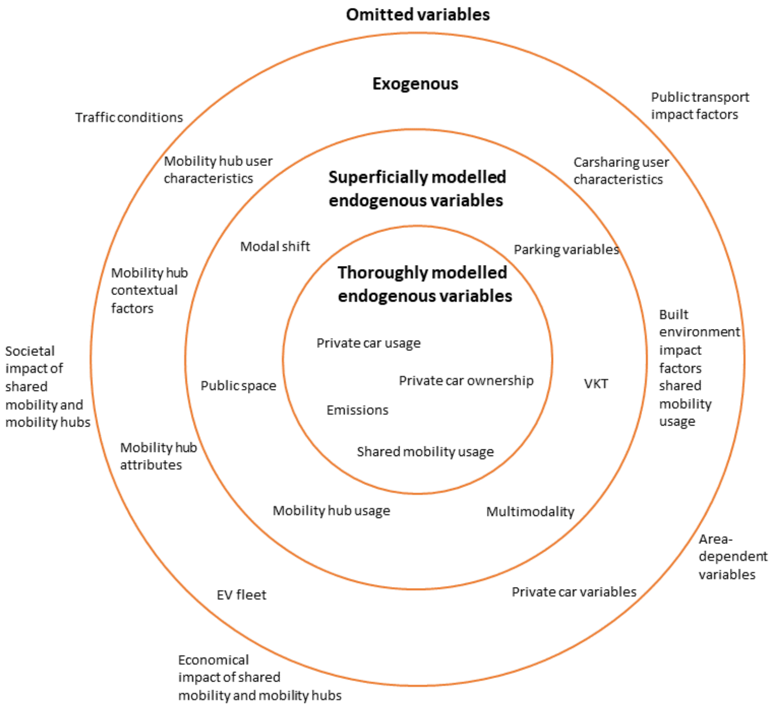


Figure 26: Bull's eye diagram

This Bull's eye diagram has provided a way to structure and scope the variables and aided in the construction of the causal loop diagram. The variables depicted in the two inner circles of the Bull's eye diagram form the core of the causal loop diagram. The exogenous variables circle is important to a lesser extent. They should be depicted in the diagram but not draw too much attention or have too many interdependencies.

Furthermore, Figure 26 can be used as a guide for, for example, policy makers for a first look into the subject of mobility hubs and distinguish the most crucial aspects. At a glance, it displays the most relevant factors and effects.

5.2. Initial causal loop diagram

Based on literature (chapter 4), UTAUT framework (section 5.1), and a Bull's eye diagram that shows which factors are not in- and excluded, an initial causal loop diagram is constructed in Figure 27.

5.2.1. Construction guidelines

For drawing up the CLD, guidelines described by Sterman (2000) and Pruyt (2013) are used. They, amongst other things, state the variable names should be nouns or noun phrases with a clear sense of direction. No verbs should be used in the variable names as the arrows and their polarities perform this role in the CLD. With respect to the links between the variables, they are causal and direct, not indirect, and should be unambiguous. Moreover, links should be interpreted under the assumption that all other variables remain unchanged. Links are relative, meaning that they indicate the change in the value related to what it would have been without the effect. Moreover, as advised by Pruyt (2013), Vensim software for system dynamics is used to draw the diagram, and different versions of the CLD are (re)drawn at different levels of aggregation and with different layouts such as curved and straight arrows to experiment with the most suitable way for the final presentation.

5.2.2. Explanation of causal loop diagram

As explained in chapter 2 Methodology, a causal loop diagram consists of four basic elements: variables, links, link signs and loop signs. A variable is something that can change over time. In this CLD, variables are purely based on the 'factors' and 'effects of Table 7 to Table 12. Variables are connected to each other with arrows. These arrows either have a + or a – sign. This implies a positive or negative causal influence. For readability purposes, the arrows are also coloured, positive causal relations are depicted with blue arrows, negative causal relations in red. Some variables are shown in a grey font between <…>. These are shadow variables that appear more than once in the model.

There is one feedback loop identifiable in the initial CLD between *parking availability* and *private car ownership*. This is a balancing type of loop, meaning that change in one direction is countered by a change in the opposite direction. The loop is therefore depicted with a 'B'.

A common practice for CLDs is to indicate whether there is a delayed causal influence by putting // on the arrow (Dhirasasna & Sahin, 2019). This principle is not applied for the construction of this initial CLD because of a lack of information regarding the time before the effect is observable. Moreover, it is expected by the author that most, if not all, causal relations take time are delayed. One time using shared mobility via the mobility hub will not immediately change people's travel behaviour and make them relinquish their private car, these decisions take time.

Variables in CLD

All in all, the CLD of Figure 27 contains the factors and relations found in chapter 4, conveniently summarised in Table 7 to Table 12. Therefore, this paragraph will not discuss all variables and arrows in detail[5] but only discusses the core.

Instead, some remarks are made on noteworthy observations or slight adaptions that are made. Such as the fact that a few variables are reformulated to match the guidelines for CLDs as previously discussed or to be able to merge variables that largely correspond. Moreover, some effects described in the literature seemed to be binary, so either the variable

[5] A more in-depth description of the meaning of the variables is provided in section 6.5, when the final version of the diagram is presented.

is true or not. Therefore, these factors are excluded from the CLD as variable names should be nouns or noun phrases with a changeable magnitude. Furthermore, as discussed in section 4.2.5, shared mobility impacts regarding public space seemed to be scarce at first instance. Therefore, extra research is done to establish relations between *shared mobility usage* and the *quality of public space*. Special attention is paid to carsharing compared to the other shared modes. The literature review indicated that carsharing is one of the most popular shared modes with potentially the most significant effects on the policy goals of reduced emissions and reduced private car usage and ownership, and improvement of public space.

Policy goals in CLD

The four themes for the policy goals, as identified in section 3.5.2, have been reformulated, as can be read in Table 13. This is done for the same reason that some variables are renamed. Because the variable names need to be nouns with changeable magnitudes and as specific as possible. For example, the term *accessibility* is somewhat ambiguous and unmeasurable. *Access & mobility options*, on the other hand, is more tangible and measurable. With a frame around the variables, the policy goals stand out from the CLD.

Table 13: Translation policy goals to variables in CLD

Policy goals	Variables in CLD
Improvement of public space	Quality of public space
Sustainable and liveable environment	Emissions
Reduction of (private) car usage and ownership	Private car usage & private car ownership
Improvement of accessibility	Access & mobility options

Core of the CLD

As mentioned before, this section will not discuss Figure 27 in detail. Anyhow, the core of the diagram consists of the 'cloud' of influencing variables for *mobility hub usage*. Then, when someone chooses to use the mobility hub, there is a choice for one of the shared modalities (bike, e-bike, cargo bike, carsharing). The usage of the shared modalities has an impact (positive or negative correlation) on one or more of the policy goals. This impact can be direct or indirect. Such as with the usage of one of the shared modalities and its effect on *emissions.* This is an indirect impact because the usage of the shared modality affects private car usage and/or vehicle kilometres travelled. This is then related to *emissions.* Similarly, mobility hub usage can impact *private car ownership*. *Private car ownership* is via *parking availability* linked to the *quality of the public space*, which is also influenced by the *emissions.*

2. What are the factors explaining the usage and effects of neighbourhood mobility hubs in literature?

The initial causal loop diagram in Figure 27 answers the second research question and visualises the factors and their causal relations that explain the usage and effects of neighbourhood mobility hubs based on literature.

The effects are the five boxed variables in the Figure 27, related to the policy goals for shared mobility and mobility hubs. The usage factors are dependent on socio-demographic characteristics (education, private car ownership), supply and demand, usage costs, psychological factors (attitude) and contextual factors (such as parking policy). These factors impact the choice to use a mobility hub. Then built environment and trip characteristics impact the choice for a shared modality, which then influences 'the effects'. The effects can be positive, i.e. mobility hubs contribute to shared mobility policy goals, however, it can also lead to opposite consequences.

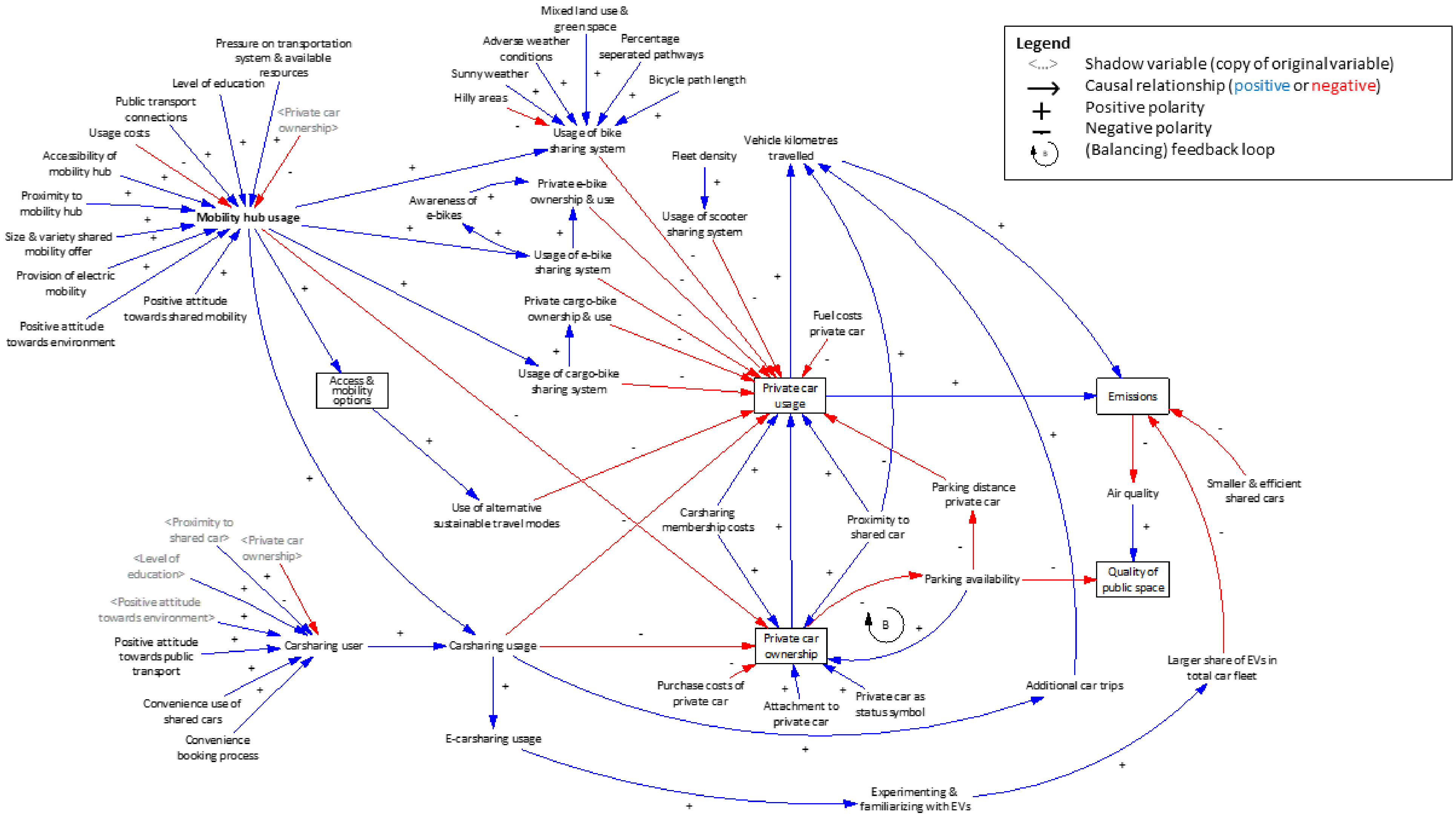


Figure 27: Initial causal loop diagram of neighbourhood mobility hub usage and effects factors

Model validation interviews

6. Model validation interviews

As explained in the methodology, semi-structured interviews are conducted with experts in the field of shared mobility and mobility hubs. The aim of the interviews is to verify the initial causal loop diagram, which is currently based on literature research. Moreover, in the interviews is determined whether the diagram correctly visualises the influencing factors and their interrelations or if it needs some adjustments or expansions to better match the practice. This step of the research is related to the methodology step of 'verification & validation' as described in Figure 5

The general procedure for the interviews is explained in section 2.4. This chapter elaborates on the parts that are specific for this round of expert interviews. This chapter will elaborate further on the specific interview procedure and the selection of participants. In the second section of this chapter, the results of the interviews are discussed, followed by a short conclusion of the interviews results. Section 6.4 contains a discussion and reflection on the interviews. And finally, section 6.5 presents the interview results in the form of an adapted, final causal loop diagram. The diagram is explained in detail, and attention is given to the adaptations with respect to the initial causal loop diagram.

6.1. Interview set up

This chapter elaborates on the interview protocol for the expert interviews. The interviews are conducted over a period of two weeks. The approximate planned duration of the interviews was one hour. Before starting the interview, the consent of each participant was asked to record the interview and use the contents for this research.

6.1.1. Expert selection

Experts in the field of shared mobility and mobility hubs are selected for these interviews. The selected participants must represent the viewpoint from a range of institutions because of their varying expertise and interest in the subject. For the selection of appropriate experts, they should have expertise in at least one of the following topics:

- travel behaviour
- shared mobility
- transport policy
- first/last mile mobility

The term expertise here implies that the interviewee has researched or has project experience in one of the beforementioned topics. The interviewees are recruited based on their expertise and first- or second-degree personal connections. Next to whether the participants meet the criteria, they are also selected based on their availability within the time frame of the interview execution.

The interviewed experts, their organisation, function, and expertise are shown in Table 14. Due to privacy reasons, the names of the interviewees are kept anonymous, and letters are used to refer to the interviewees.

Table 14: Participants of expert interviews

Expert referred to as	Organisation	Function	Expertise
A	Arcadis	Consultant	Experience with mobility projects in general, some specific projects on mobility hubs but most of the time mobility hubs are part of the total mobility concept. Clients are municipalities, provinces, sometimes national government.
B	Arcadis	Junior consultant	Graduated on topic of potential effects of mobility hubs. Since then, worked on multiple projects on mobility (policies) of which shared mobility and mobility hubs are part of.
C	Witteveen+Bos	Project engineer	Involved in multiple projects regarding urban mobility in combination with spatial issues from municipalities or provinces. Shared mobility and mobility hubs can be part of the solution
D	Rijksuniversiteit Groningen	Junior researcher	Research on mobility hub program in Groningen and Drenthe (reisviahub) for OV-Bureau Groningen Drenthe. The aim of the research is to look at the governance of the hubs in Groningen and Drenthe, compare that to some international examples and develop an evaluation framework.
E	TU Delft	Postdoc Transport & Planning Department	Research experience in electric vehicles and shared mobility (impacts). Currently working on the European eHUB project exploring general population's preference for eHUBS.
F	TU Delft	Assistant professor Transport & Planning Department	Many years of research experience in shared mobility, carsharing, automation. Operational research as well as behaviour modelling. Since 2018 involved in shared mobility hubs and the eHUBS project.
G	CROW	Program manager transport nodes and mobility hubs	Often works on complex, multidisciplinary projects that require input from different knowledge teams in CROW that involve, mobility, public transport, and spatial aspects such as mobility hubs.

6.1.2. Interview guide

The aim of this round of interviews is threefold. Namely:

1. expand the model by identifying new variables and links
2. verify the current variables and links of the initial CLD
3. identify critical variables and links and get a sense of the degree of importance.

To ensure that these objectives of the interviews are fulfilled, the same general structure of the interviews is used in each interview and consists of six phases. Table 15 lists these phases and shortly explains the objective of each phase. The complete standard interview guide, including questions, can be found in Appendix F.

Table 15: Phases and objective per phase of expert interviews

	Phase	Objective
1	Introduction of research	Briefing of interviewee on research and interview
2	Participant introduction	Getting insight in interviewee's expertise and involvement with mobility hubs
3	Validation of most important factors and relations	Possibly identify new variables and missing links and verify current variables and links in CLD
4	Explanation of CLD	Explaining where the current CLD is coming from and making sure interviewee understands how to read the CLD
5	Expert's view on effects and factors: discuss CLD per variable	Verify current variables and links in CLD and possibly identify new variables and missing links
6	Final closing questions	Identify level of importance of variables and links

6.2. Interview results

By applying the data analysis process as described in section 2.4.3, the approved transcripts of the interviews are grouped and categorised to enable drawing conclusions from the obtained qualitative data. The transcripts are not included in this thesis but can be requested from the author.

This section discusses the suggestions made by the interviewees to expand and adjust the initial causal loop diagram (Figure 27 on page 66). The letters A to G are used to refer to the interviewees, as in Table 14. The discussion on the results is split up into five parts. Section 6.2.1 reviews the benefits and goals of mobility hubs. The next three sections consider the actual initial CLD and possible improvements. This is followed by section 6.3, which provides a short summary of the results and answers sub research question 3.

6.2.1. Benefits and goals of mobility hubs

The first questions of the interview are about the perceived benefits of a mobility hub and the reasons for a municipality to implement a mobility hub. The obtained answers are largely similar to each other and in line with the identified policy goals for shared mobility and mobility hubs (improvement of public space, sustainable and liveable environment, reduction of (private) car usage and ownership, improvement of accessibility). Interviewees A, C, F and G all mention that a mobility hub is a way to aggregate shared mobility in a physical point which makes regulation possible for municipalities. In that way, these shared vehicles create as little nuisance as possible, and the space can be used efficiently and enables the space to be multifunctional. Preferably so, that it does not only focus on mobility but can also serve as a socially attractive place to meet and to stay.

Every interviewee mentioned that a hub or shared mobility could help in the mobility transition and contribute to more sustainable travel behaviour. This is largely due to providing alternatives for using and/or owning a private car which has several benefits in terms of the environment, the use of public space directly influenced by parking pressure and improving the accessibility and mobility options.

In addition to the current policy goals and the ultimate effects of shared mobility, [B] discusses that also noise pollution, traffic delays and travel times are interesting variables to consider. They are related to car usage (private and shared).

6.2.2. Factors influencing mobility hub usage

The most relevant statements from the experts made on the variables around mobility hub usage in the initial CLD are summarised in Table 16. Specific possible changes (additions or deletions of variables and links) to the diagram are shown with 'Add: …' or 'Remove: …'. In the text below the table, more explanation and context are given, categorised per topic. Some comments in Table 16 and Table 17 are orange coloured. This indicates the comments that are actually implemented in the construction of the final CLD. The author used its own judgement to choose which comments are useful and in line with the scope and goal of the diagram. The changes made need to be substantiated and add value to the diagram. For example, [D] and [G] made some suggestions along the lines of the location of the hub and its network (interchangeability of vehicles). While the author indeed estimates that this could be influencing the mobility hub usage, this is not within the neighbourhood mobility hub scope of this research. Therefore, these comments are not implemented.

Table 16: Opinions from interviewees on mobility hub usage in initial CLD (Figure 27 on page 66). Comments in orange are adjusted in final CLD.

Interviewee	Comments on *mobility hub usage* variable in initial CLD
A	• More personal characteristics of influence • Add: safety and parking policy • Add: feedback loop supply and demand • Add: link between supply and quality of public space
B	• More socio-demographic aspects • Doubt on effect of provision of electric mobility • Add: availability
C	• More personal characteristics – define categories • Many more attitudes imaginable • Add: quality requirements/appearance – level of service • Add: information of availability • Add: social safety
D	• More socio-economic factors • Add: comfort variables - level of service • Add: location of hub
E	• Define categories for socio-economic factors, attitudes, current mobility patterns and mobility behaviour • Add: experience with shared mobility • Add: social influence • Add: availability of vehicles • Add: ease of use and payment
F	• Draw feedback loop car ownership and hub usage • Add: private car usage and parking influences pressure transportation system & available resources • Remove: no need for distinction accessibility and proximity • No need to make attributes specific • Organise variables in supply and demand categories
G	• Add: social aspect of mobility hub • Parking policy in neighbourhood itself and nearby neighbourhoods of influence • Information on availability – MaaS • Ease of exchange between vehicles from different hubs

Personal characteristics

Every interviewee somehow remarked that personal characteristics are important in the choice to use the mobility hub and its modalities. Because in the initial CLD, only education was included, this suggested that only that variable is relevant, which is probably not correct. It would make more sense to introduce categories of factors in the model instead of listing them one by one. They suggested including, for example, a category of *personal characteristics*. This category then likely includes variables such as age, gender, level of education, income, type of household, occupation, vehicle ownership. It would be more correct to bring them together as one relevant category instead of insinuating that each of these individual factors is very important. Other categories are *psychological factors, level of service, trip characteristics, built environment characteristics* and *private car variables.*

Psychological factors

Besides introducing the *personal characteristics category,* [C] also suggests identifying other categories such as *psychological factors*. Based on other interviews, this category could include a person's *attitudes* and *experience* [A, B, C, E, F] and *social influence* [E]. [C], [E], and [F] argue that there could be many personal attitudes which influences the usage of shared mobility and a mobility hub and that it is impossible to capture them all. Besides, attitudes are closely linked to mobility behaviour and may therefore be already, albeit indirectly, included in the diagram.

Level of service
Another group of variables that are not included in the initial CLD but are perceived to be important to interviewees [A], [C] and [D] are safety, comfort, and quality aspects of the mobility hub. Because those variables are very subjective, they agree to summarise this in *level of service*.

Parking policy
Interviewees [A], [F] and [G] mention that the *parking policy* in the catchment area of the mobility hub is a significant factor in the usage of the mobility hub. Without some kind of *restrictive parking policy* such as limited or paid parking, residents will not so easily start to use the mobility hub as there are no or limited push factor(s). When residents are able to park their private cars in front of their house for free, there is no incentive to start thinking about alternatives [A]. The variable *parking policy* should be related to *pressure the transportation system & available resources,* which then depends on the *private car usage* and the *parking availability* [F].

Supply and demand
In addition to the general supply of shared mobility variable *size & variety of shared mobility offer*, some interviewees [A, B, C, E, G] suggested adding a variable for the *availability of shared vehicles* to stress the need for a good balance between the supply and demand in the mobility hub [A]. As stated by [G], "When a vehicle that a (new) user was planning on using is not available at the hub when he/she arrives there for the first few times, they tend to shut out the mobility hub entirely". [C] and [G], therefore, would also like to add a variable regarding the *information on availability of shared vehicles*, so the user knows when and where which vehicles are available. Moreover, one could also say that the supply, *size & variety of shared mobility offer*, directly impacts the quality of public space as stalling more vehicles is at the expense (of the *quality) of public space*, so an additional link between those variables is possible [A].

[D] adds that the *location* of a mobility hub is important with respect to usage. When a hub is located in a densely populated area, and many activities are nearby, the usage of the mobility hub will be higher versus a hub located at the city edge.

[B] expressed his doubts regarding the impact of the *provision of electric mobility*. He argues that the degree of influence strongly depends on the type of person and its attitudes.

6.2.3. Effects of mobility hubs
Moving onto the effects of mobility hubs, Table 17 presents an overview of the main things mentioned by the interviewed experts categorised in several themes. In the text below the table, more explanation and context are given, categorised per theme (column). Just like Table 16, some comments are orange coloured. This indicates the comments that are actually implemented in the construction of the final CLD.

Table 17: Opinions from interviewees on mobility hub effect in initial CLD (Figure 27 on page 66). Comments in orange are adjusted in final CLD.

Inter-viewee	Usage of shared modalities	Carsharing	Private car variables	Other
A	• Particularly carsharing reduces private car usage	• Add: link between sustainable modes and carsharing • Remove: additional car trips, confusing term • Many overlap between carsharing user variables and mobility hub usage variables	• Very specific variables, not in line with level of aggregation rest of model	• Remove: access & mobility options
B	• Particularly carsharing reduces car usage and ownership, less so for other modes • Many (personal/trip) factors identifiable that influence the choice between individual shared modes	• Add: link between shared modalities and public transport • Add: attitude towards shared mobility and public transport • Add: link between attitude towards environment and usage of electric mobility • Additional car trips confusing term	• Add: link private car usage and quality of public space	• Add: Noise nuisance, traffic congestion and delays as extra policy goals
C	• Add: link between car ownership and public transport use • Many more factors that influence usage of shared modalities such as baggage, trip length • Introduce categories on higher level	• Introduce categories for user and trip characteristics		• Make scope of mode clear, to what kind of hub is this model applicable
D	• Choice between shared modalities depends on trip characteristics • Add: information on availability of vehicles in hub • Add: comfort variables • Add: location of hub (city vs. city edge) is of influence on usage	• Add: Attitude public transport and cycling (influences carsharing user)		
E	• Effects of shared modalities on private cars probably very small	• Add: feedback loop e-carsharing usage and larger share of EV • Merge factors for carsharing user with factors for mobility hub usage	• Remove: costs and proximity not directly related to car usage but via hub usage • Add: link between private car ownership and emissions	• Access & mobility options should affect general shared mobility use, not individual modes
F	• Add: link between usage of electric cargo-bike and e-bike (also applies to other modes) • Add/Remove: inconsistency awareness variable • Add: average trip length influences choice between modalities	• Add: link between experimenting with EVs and car ownership • Merge factors for carsharing user with factors for mobility hub usage		• Add: average tip length variable (and link to VKT)

Inter-viewee	Usage of shared modalities	Carsharing	Private car variables	Other
G	• Add: social aspect of mobility hub • Not only parking policy in neighbourhood of importance but also adjacent neighbourhoods of the hub			• The (road/public transport) network and infrastructure must act as a facilitator

Usage of shared modalities

Interviewees A and B mention that particularly *carsharing usage* reduces *private car usage,* and for the other shared modalities (bike, e-bike, and cargo bike sharing), the effect is debatable or rather small [E]. They, therefore, suggest that there should be a two-way link between the *use of alternative sustainable travel modes* and the usage of the shared modalities. Positive experiences with shared mobility could stimulate users to use other sustainable travel modes more often (active (shared) modes or public transport). And on the other side, (non-car owning) users will use shared mobility on some days and other days use (private) active modes or public transport.

[B], [C], [D], [F], [G] bring up that the model could possibly be expanded with variables that affect the choice between the different shared modalities. For instance, personal characteristics as well as the built environment and trip characteristics, supply, and costs are of influence. In addition, [F] also describes that the usage of one modality could influence the usage of another, such as via the experience with electrically powered bikes and cargo bikes. Besides, the variable of *awareness of e-bikes* is inconsistent with the cargo bike variables and should therefore either be deleted or also added with respect to cargo bikes [F].

Carsharing

Every interviewed expert reflected on the variables for *carsharing user*. They either mentioned that there is a lot of overlap between the variables for *carsharing user* and *mobility hub usage*, or they bring up extra variables. With respect to *e-carsharing usage*, [E] mentions that there can be a feedback loop distinguished between *e-carsharing usage* and *larger share of EVs in total vehicle fleet*. When there are more EVs, there is a higher chance of shared vehicle being electric which increases the *e-carsharing usage*. [F] speaks about the variable of *experimenting & familiarizing with EVs,* which could also increase the *private car ownership* when they are enthusiastic about electric vehicles and want one themselves.
From some of the interviews follows that the term *additional car trips* is a bit confusing. Additional to what, they then questioned. This variable should thus be removed or renamed [A, B]. And when talking about *additional car trips* and *VKT*, there should be a variable of *average trip length* that influences the *VKT* and could also be linked to the usage of the shared modalities [F].

Private car variables

[A] mentions that the variables such as the *costs of private car* and the *attachment* are too specific in comparison to the other variables in the model. Moreover, by including these variables, it seems like they are the only ones affecting the system, but there are many more private car variables identifiable. Moreover, [E] points out that the *costs* and *proximity of carsharing* are not directly related to *private car usage* but via *mobility hub usage*. Therefore, these variables should be omitted in this part of the diagram, and the addition of *a private car variable category* could support the notion that private car variables impact the ownership and usage of a private car, but within the scope of this research they are not further specified. Moreover, *private car usage* should have a direct link to *quality of public space*, for example, when due to high transport demand, the road needs to be broadened or more in general, a busy road is less attractive than an almost car-free area [B]. *Private car ownership* could also be directly linked to the emissions variable due to the emissions caused in the production phase [E].

Accessibility
[A] and [E] expressed some confusion on the variable of *access & mobility options*, the usage of a mobility hub does not include the *access & mobility options*, but the presence of a mobility hub does. This variable should therefore be at the same level as the factors that affect shared mobility usage in general. It could either be moved to the left or removed from the model [A, E].

6.2.4. Most important variables and correlations

In the final part of the interview, the experts are asked to identify what they perceive as the most critical and important variables and relations. Due to limited time, this is not discussed with [F], but the other six experts named a total of fourteen variables. *Proximity*, supply (*size & variety of shared mobility offer*), *parking policy* and costs are mentioned by three interviewees. Other factors that are mentioned twice are *accessibility*, the social aspect of mobility hub, *availability of vehicles* and *information of the availability*.

The most important links are between *mobility hub usage* and *carsharing usage*, *carsharing usage* to *private car ownership*, *private car ownership* to *parking availability* and from *parking availability* to *quality of public space*. Also, the links between *private car ownership and usage* are strongly present, as well as from *private car usage* to *VKT* and to *emissions*.

6.3. Conclusion interview results

In general, the experts agree with the core of the diagram. The main take-aways from the interviews are the specific suggestions for adjustments to the model. Some suggestions are only minor, while others are more radical. The comments made by the experts are judged by the author on which to implement and which not. This is based on whether they are in line with the scope of the diagram and research and can be substantiated.

The textbox below answers the third research question and summarises the most important changes that need to be made based on the experts' opinions and the perception of the author.

3. To what extent does practice confirm the usage factors and effects, of neighbourhood mobility hubs, obtained from literature research?

The interviewed experts have largely confirmed the initial diagram that was purely based on literature research. However, they did some suggestions for adjustments which have been summarised in Table 16 and Table 17. The core of the diagram can remain unchanged, but some comments are made for:

1. Introduction of categories: level of service, psychological factors, personal characteristics, trip characteristics, built environment characteristics, private car variables. These categories then include several variables that need not be mentioned specifically but are of influence
2. Removal of access & mobility options variable. Though this variable is related to one of the policy goals, some experts expressed their confusion on this variable, because the usage of a mobility hub does not lead to more *access & mobility options*, but the presence of a mobility hub itself does.
3. Merger of carsharing and mobility hub variables. The initial CLD treats carsharing variables separately from general mobility hub variables. Because of the large overlap, these variables need to be merged into factors that influence the *mobility hub usage*.

Some other minor comments are made along the lines of improving the consistency in the diagram.

6.4. Discussion expert interviews

In this section, some points of discussion with respect to the expert interviews are discussed. Firstly, attention is paid to the saturation and the second part of the section contains some remarks on the diagram itself, followed by a discussion on the experts.

6.4.1. Interview saturation

Figure 28 shows the number of new insights gained from the interviews with respect to the verification of the initial causal loop diagram. In the first interview, all mentioned suggestions for adding a variable and/or relations or deleting something from the CLD are counted as new insights. A new insight in the following interviews are things they mention that should be added to or deleted from the model and have not already been mentioned by previous interviewees. Note that the order of the interviews is not similar to the sequence of the experts from A to G.

Many interviewees started to list several socio-economic factors that were not included yet, but since they also suggested summarising this into one category, these are not considered in the counted number of new insights. Because this would not make a fair comparison (some people mentioned six extra variables within the category while others only made a suggestion to create a category and research additional factors).

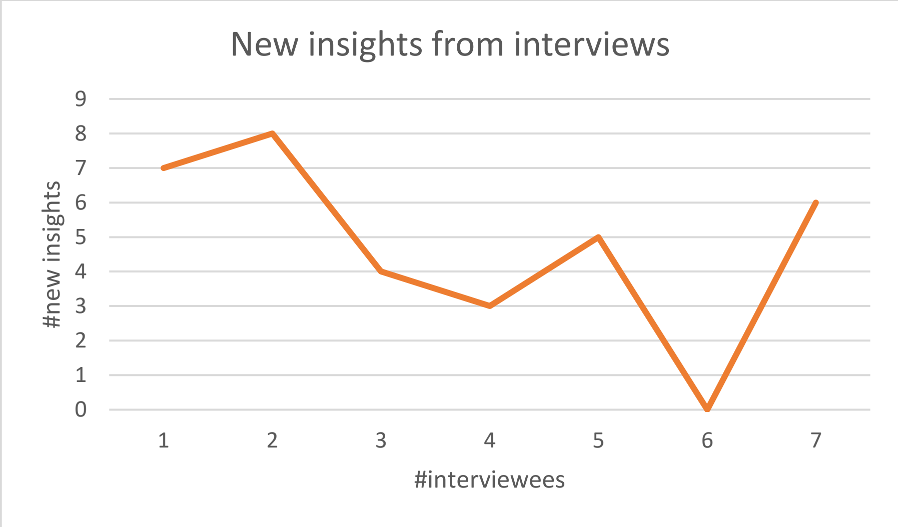


Figure 28: Saturation graph of interviews

Figure 28 implies that the data collection is not necessarily complete. There is no saturation yet. Interview numbers 5 and 7 gave new added insights with respect to their predecessors. This can possibly be explained by the fact that the interviewees have different backgrounds and work at different organisations (consultancy, academia, knowledge institute). Interviewees that were more familiar with shared mobility research and the system dynamics and causal loop diagram methodology (i.e. interviewees 5 and 7) tended to be more likely to question the current variables and relations more extensively and thus also come up with possible new additions. Figure 28 only shows the absolute number of new insights but does not show the relative importance of the new insights, which might give a slight misrepresentation. Moreover, the diagram, in theory, could be extended infinitely with extra variables and correlations. Therefore, and also because of time restrictions, it is chosen to leave it at the seven interviews and use the gained input and their reasoning to thoroughly study the model, trying to decide if everything inside the scope of this research is properly included.

6.4.2. Reflection diagram

As the initial causal diagram is purely based on literature, it was known to the author beforehand that the diagram was not complete and, in some ways, inconsistent. However, this meant that some of these points were often mentioned by different experts. This applies, for example, to the personal characteristics and the comment that not only *level of education* is of influence but that there should be many more. It did influence the interviews in a way that relatively a lot of attention was paid to detailed, disaggregate variables. This experience makes it clear that presenting an aggregate version of the model or slowly building up and expanding the model is useful in presenting the model in the future.

Also reflected in the interviews is the fact that many, if not all, of the effects, are long term effects. The current style of the diagram did not capture that. In the system dynamics approach, it is common to use delay signs on arrows. However, no delay signs are applied in this diagram because the amount of time before the effect occurs, is either unknown or one could argue that every correlation is delayed, and this is not so evident in the current diagram.

6.4.3. Reflection experts

Furthermore, it must be noted that the interviewed experts are potentially biased in the sense that because they are very involved with shared mobility, they generally tend to be rather positive towards the effects of mobility hubs. Moreover, as shared mobility and mobility hubs are in an early development phase, the current users are the early adopters who may not be necessarily representative for the total population. Thus, it could be the case that at the moment the effects of mobility hubs are quite positive since early adopters are very concerned with sustainability and reduce their private car usage and ownership, but the early and late majority may only see a mobility hub as an addition to their current mobility options.

The interviewed experts are chosen based on their expertise. Nevertheless, not all of their comments are, without a doubt, used for the adaptation of the diagram, as can be seen in Table 16 and Table 17. The author used its own judgement to choose which comments are useful and in line with the scope and goal of the diagram. For example, there are some comments made on the addition of variables related to public transport. However, since this is not within the scope of the research and the diagram, those are not implemented.

Finally, for the invited experts, there is started within the author's own network. There are possibly other experts (outside of the network) that could have added extra value.

6.5. Final causal loop diagram

Based on the expert interviews in which the initial causal loop diagram is discussed, the diagram is adapted to a final causal loop diagram. This causal loop diagram is one of the end products of this thesis and forms the basis for the evaluation interviews of some currently existing mobility hubs in the Netherlands. In this section, the diagram will be discussed in detail. The total diagram is depicted in Figure 34, and for clarification of the text, some cut-outs are made. A more aggregate version of the diagram with only the most important variables and relations included is shown in Figure 35.

The starting point for reading the diagram is at the left side at *mobility hub usage*. *Mobility hub usage* means the usage of the mobility services offered at the hub. There are several variables that influence the usage of a mobility hub (from top to bottom in Figure 29):

- Displayed above *mobility hub* usage, there are three variables with icons, level of service, *psychological factors,* and *personal characteristics*. These are actually categories that could include many other variables, such as the ones depicted above. It shows that these variables are possibly relevant though not completely within the scope of this research, or the precise impact is not fully established in literature and practice. Level of service variables are things like safety (perception), comfortability and/or convenience in the usage of the mobility hub. Psychological factors are variables such as attitudes, previous experiences or social influences that affect how someone feels about using the mobility hub. Personal characteristics are things like age, gender, income, level of education etc.
- The variable *public transport connections* refers to the presence and number of public transport connections at the mobility hub. When there are more connections, like bus/tram/metro/train stops nearby, the attractiveness of the mobility hub as a transit node increases, and so does the usage.
- The variable *accessibility & proximity of mobility hub* specifies how easy the hub can be accessed by all (potential) users. For example, where is it located, and if it is and accessible 24/7 or only during work hours. The second part of the variable (proximity) relates to how close the hub is to the (potential) users. The closer to people's homes or destinations, the more likely they are to use the mobility hub.

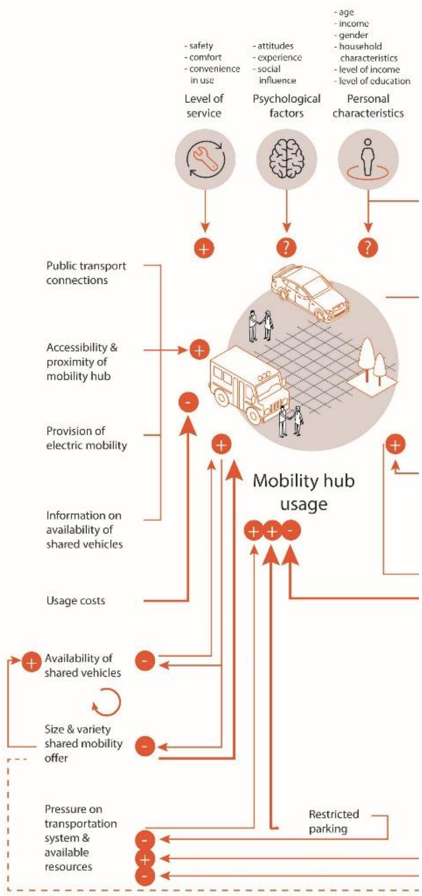


Figure 29: Diagram cut out of influencing factors mobility hub usage

- Then there are several variables with respect to the mobility supply at the hub. Of which one being the *provision of electric mobility*. More electric vehicles offered could positively influence the chance of using the hub for some people.
- *Usage costs* are negatively correlated to mobility hub usage. When the costs for using the services at the mobility hub increase, the usage likely decreases. In the expert interviews, the costs variable and the link between costs and usage are identified as critical and therefore displayed with a thicker arrow.
- When the *size & variety of the shared mobility offer* increases, i.e. there are more vehicles and/or more different types of shared mobility, the usage of the mobility hub increase. This brings us to a positive feedback loop between supply and demand. When the supply, *size & variety of shared mobility offer* increases, so does the usage, which in turn stimulated the supply to grow and so on.
- Not only is it relevant to have a large *size & variety of the shared mobility offer,* but these vehicles must also be available at times when people want to use them. This is the *availability of shared vehicles* variable.
- Moreover, *information on the availability* is also crucial. Users want to check before deciding on making the trip that their desired vehicle is available. Here is also a feedback loop identifiable between the usage and the availability. Higher usage means, on average lower availability, and when the size & variety does not change, this will lead to eventually decrease the usage again as people lose trust in having a vehicle available when they need it.
- Then at the bottom is the variable of *pressure on transportation system & available resources.* The pressure on transportation system & available resources is influenced by *parking availability, private car usage*, and *restricted parking* (parking policy) and thus means in neighbourhoods with a high parking pressure (low *parking availability*) or paid parking, people are more likely to use a mobility hub.
- Another variable that influences mobility hub usage (not completely visible in Figure 29) is *private car ownership*. People with no or low private car ownership are more likely to use the mobility hub.
- And finally, there is also a feedback loop between *mobility hub usage* and the usage of the individual shared modes. Positive experiences with one shared mode at the mobility hub may stimulate the usage of the mobility hub in general and possibly induce the usage of also other modes.

Moving to the right in the diagram (see Figure 30 for a cut out), the usage of the mobility hub increases the usage of the shared modalities such as bike, e-bike, cargo bike and (e-)carsharing as alternative (sustainable) travel modes. Alternative to private car usage. The usage of these shared modalities is, besides the general influencing factors for mobility hub usage, also dependent on specific variables that determine the choice between these modes, such as *personal characteristics*, *trip characteristics* and *built environment characteristics*. These are again container concepts that include a collection of factors, of which some are depicted above. It is not possible to express these correlations as either positive or negative, and for some, the degree of influence is questionable. That is why they are depicted with a *?*.

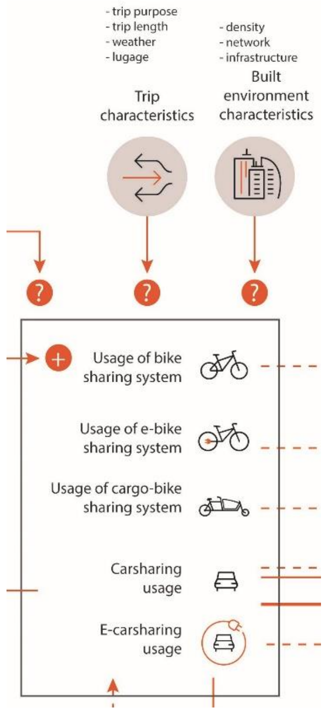


Figure 30: Diagram cut out of shared modalities

The *usage of (e-)bike sharing* and *cargo bike sharing* could decrease *private car usage*. But since this impact is still a little bit uncertain and probably very small, these links are shown with dashed lines. Carsharing is seen as the most important shared mode at the mobility hub. Though, the effect of carsharing on private car usage is debatable. Some carsharing users might use the shared car instead of their own private car, but others may use it in addition to their private car usage. Therefore, the link between *carsharing usage* and *private car usage* and *vehicle kilometres travelled* has a *?*. Less private car usage (which is also dependent on some *private car variables*) reduces the *emissions* and potentially also impacts the *quality of public space*. *Carsharing usage* is also related to *private car ownership*. Some studies have shown that carsharing usage eventually leads to lower car ownership.

Finally, there is also the variable of *e-carsharing usage*. Electric shared cars for some people offer the opportunity to experience electric vehicles and familiarize themselves with electric driving. It may happen those users become enthusiastic and buy an electric vehicle for themselves, which increases the *private car ownership* or trade their current fossil-fuelled car for an electric one which increases the total *share of electric vehicles (EVs) in the total car fleet*. A higher share of electric vehicles also increases the chance of a shared vehicle being electric, and these three variables thus form a reinforcing feedback loop (Figure 31). Electric vehicles produce zero direct emissions (negative correlation between the *share of EVs in total car fleet* and *emissions*), which again is beneficial for the *air quality*.

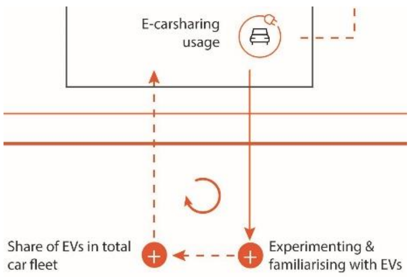
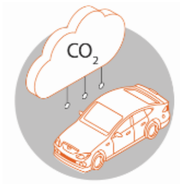


Figure 31: Diagram cut out of e-carsharing feedback loop

On to the variable of *private car ownership*. Higher private car ownership negatively affects the *parking availability* in a neighbourhood, but the other way around, the amount of parking nearby could also affect people's choice to own a private car. This is, therefore, a balancing feedback loop. When the *parking availability* is high, the average distance to the parked private car is low, which means that in general, people are more tempted to use the car (higher *private car usage*) in comparison to when the car is parked far away. In other words, there is a negative correlation between *parking availability* and *parking distance to private car* and *parking distance private car* and *private car ownership* is again negatively correlated. Besides, there is also a direct link between *private car ownership* and *private car usage*. Higher ownership logically means more usage.



Not yet discussed in detail is the variable of *emissions*. This is logically dependent on *private car usage* (link presented with thick arrow) and *vehicle kilometres travelled*. *Emissions* again correlate via *air quality* to the *quality of public space*. Fewer *emissions* mean better *air quality* and thus a higher *quality of the public space*. Lastly, apart from *air quality*, the *quality of public space* revolves around the *parking availability* (many parked cars significantly reduces the quality of the public space), *private car usage* and possibly also the *size & variety of shared mobility offer*.

The corresponding legend of the diagram is shown in Figure 32. As explained in the text above, the correlations are depicted with a + or a – sign where possible. In some cases where it was not possible to identify a polarity, a *?* is assigned to the arrow. Furthermore, the thickness of the arrows corresponds to the level of importance of the relationship, and this distinction is based on the experts' opinions as described in 6.2.4). The aggregate version of the model is shown in Figure 35.

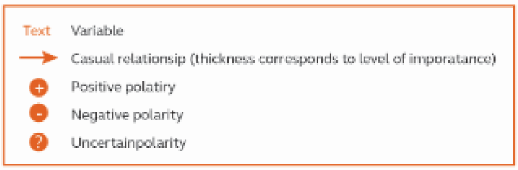


Figure 32: Legend of final causal loop diagram

6.5.1. Main differences between initial and final CLD

Section 6.2 has described the comments made by the experts. Section 6.3 has shortly described the main take-aways from the interviews. In this section, the three most significant changes are discussed in more detail.

Firstly, the experts advised on the introduction of six categories (see Figure 33). At first instance, only level of education was included as a personal characteristic. This was done because only for this variable conclusive evidence was found on the type of correlation (positive or negative). For other factors such as age and income, no definitive type of correlation was identified. Therefore, those variables were left out of the diagram. However, the experts rightly expressed that these variables, such as the user's age, income, gender etc. does influence the usage of a mobility hub. They suggested that by introducing categories mentioning these variables as 'sub variable', it is acknowledged that these variables play a role, but there is no need to assign a type of correlation explicitly. Moreover, the identification of personal characteristics is not the main focus of this research.

Figure 33: Diagram cut out of variable categories

Another important adjustment is the removal of the *access & mobility options* variable. Though this was related to one of the policy goals, some experts expressed their confusion on this variable because the usage of a mobility hub does not lead to more *access & mobility options*, but the presence of a mobility hub itself does. It is thus illogical to couple this to mobility hub usage. And because this variable is already implicitly included in the shared modalities, it is decided to remove it from the diagram.

Thirdly, in the initial CLD, there was a clear distinction between the *mobility hub usage* and its shared modalities and carsharing specifically. This was done because some of the literature used for composing the CLD was focused on carsharing. Nevertheless, the interviewed experts believed there is a lot of overlap between the carsharing and mobility hub usage factors. It is thus decided to merge these variables into factors that influence the *mobility hub usage*, and carsharing is just one of the shared modes available at the mobility hub.

Finally, other (smaller) changes made to the model are explained in section 6.2 and shown in Table 16 and Table 17.

6.5.2. Aggregate causal loop diagram

As briefly mentioned before, an aggregate version of the final CLD is displayed in Figure 35. This diagram only shows the most important variables and correlations and can be used for those readers interested in a simple overview of mobility hub usage and effects. The aggregate version contains all thick arrows of the full diagram and their associated correlations and feedback loops, if applicable. These variables are identified with the help of the experts as described in section 6.2.4.

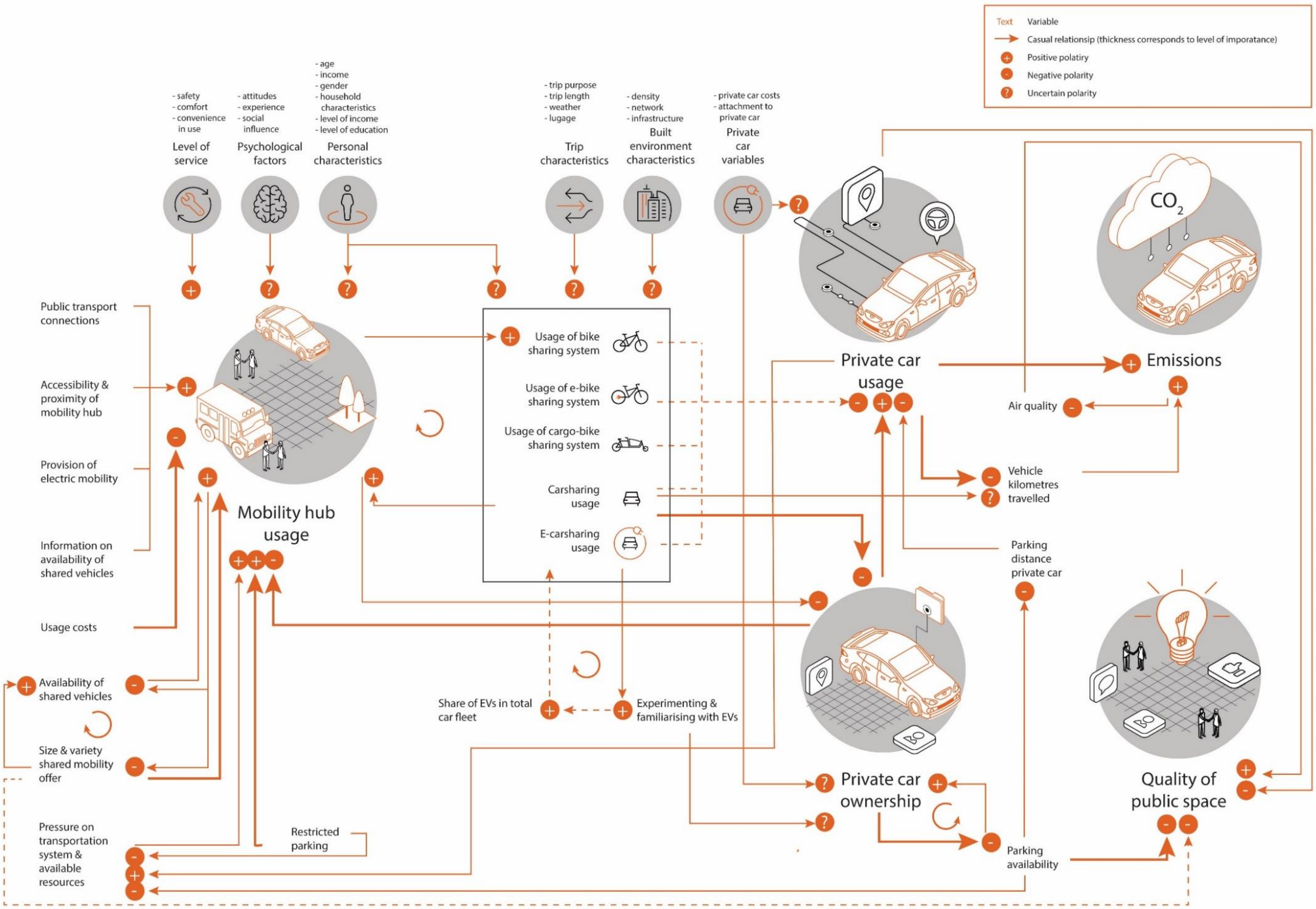


Figure 34: Final complete causal loop diagram of neighbourhood mobility hub usage and effects factors

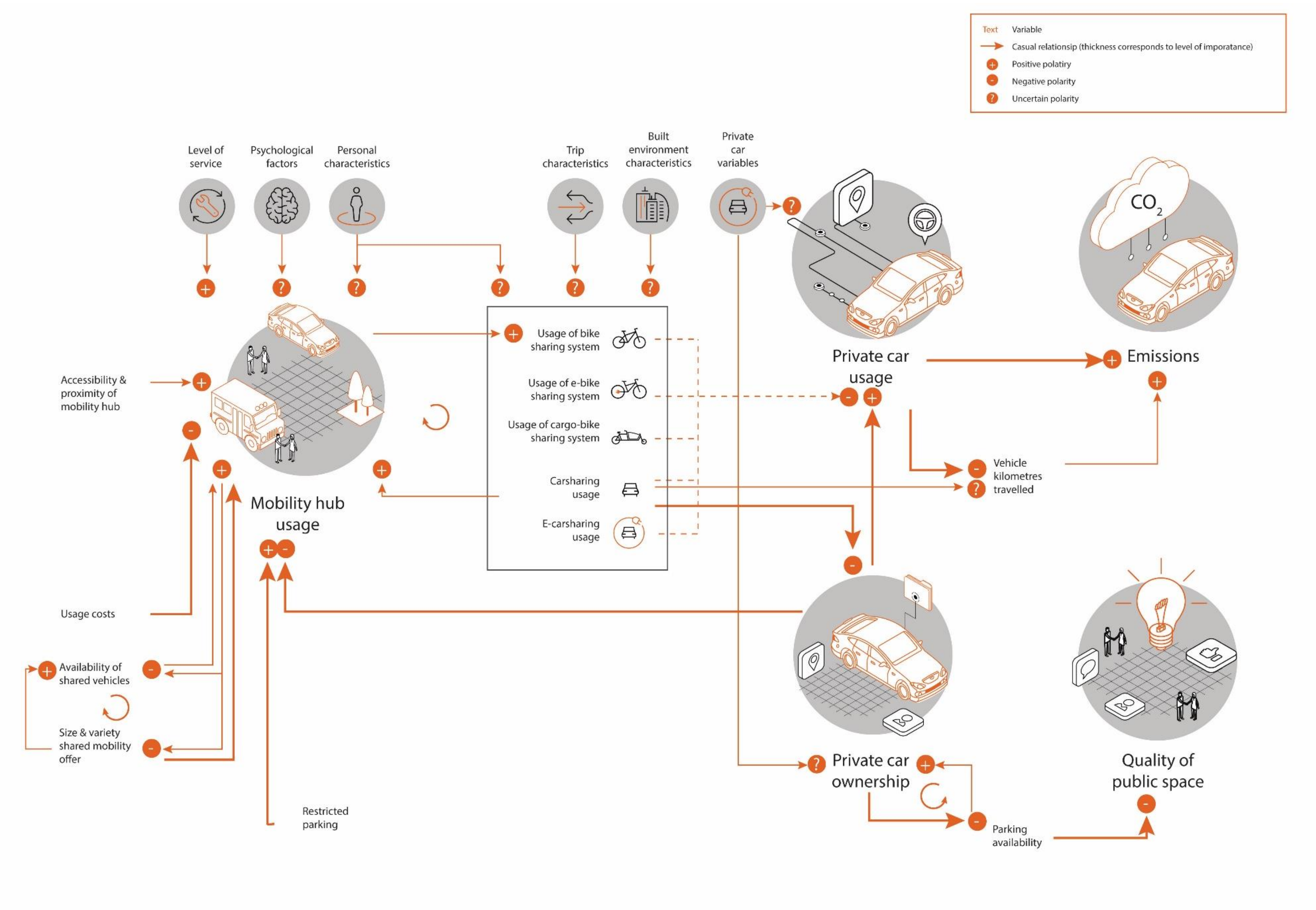


Figure 35: Final aggregate causal loop diagram of neighbourhood mobility hub usage and effect factors

Ex-post evaluation of mobility hubs

7. Ex-post evaluation of mobility hubs

As explained in the methodology chapter, 2.4, semi-structured interviews are conducted with stakeholders of existing mobility hubs. The aim of the interviews is to gather stakeholders' perceptions on the usage and effects of the existing mobility hubs of which they are/were involved and evaluate these effects based on the established diagram. This step of the research is related to the methodology step of 'model use' as described in Figure 5.

The general procedure for the interviews is explained in section 2.4. This chapter elaborates on the parts that are specific for this round of expert interviews. This chapter will elaborate further on the specific interview procedure and the selection of participants. In the second section of this chapter, the results of the interviews are discussed, followed by a conclusion in section 7.3 and a discussion and reflection on the conducted interviews in section 7.4.

7.1. Interview set up

This section elaborates on the interview protocol for the second round of interviews for the evaluation of existing mobility hubs. The interviews are conducted over a period of two weeks. The approximate planned duration of the interviews was one hour. Before starting the interview, the consent of each participant was asked to record the interview and use the contents for this research.

7.1.1. Participant selection

For this round of interviews, participants were selected that are involved with existing mobility hubs in the Netherlands. See section 3.3.2 for an overview of the existing neighbourhood mobility hubs in the Netherlands. Based on that inventarisation, whether or not the municipalities have a shared mobility policy (section 3.5.2) and available contacts, it is chosen to interview four municipalities (Amsterdam, Nijmegen (indirectly also Arnhem), Delft, Schiedam). To also have another perspective, Hely and Cargoroo are invited as a shared mobility/hub providers. Next to whether the participants meet the criteria, they are also selected based on their availability within the time frame of the interview execution.

Amsterdam and Nijmegen (and Arnhem as a sub partner of Nijmegen) participate in the European eHUBS project and have thus been busy last year with the implementation of eHUBS. As both cities have a different approach to the implementation process in terms of governance and are in different phases of progress, these interviews would make a great opportunity for a comparison. The municipality of Delft is interviewed because despite Delft being a 'medium-sized' city, there are very innovative and have been forerunners in the field of shared mobility and mobility hubs. For example, one of the first Hely hubs is located in Delft. Hence, both the municipality and Hely are interviewed to talk about this hub and their plans for the future. Also, the municipality of Schiedam seemed to be an interesting party to question with their similarities to Delft and currently four existing mobility hubs (albeit only carsharing). Finally, Cargoroo as a, currently rapid expanding provider of shared cargo bikes, is invited to talk about their vision on multimodal hubs. Moreover, Cargoroo is also involved with the eHUBS in Amsterdam, Nijmegen, and Arnhem.

The interviewed persons, their organisation and function are shown in Table 18. Due to privacy reasons, the names of the interviewees are kept anonymous, and letters are used to refer to the interviewees.

Table 18: Participants of mobility hub evaluation interviews

Expert referred to as	Organisation	Function
H	Municipality of Amsterdam	Project manager eHUBS project Amsterdam
I	Municipality of Nijmegen	Policy advisor and project manager eHUBS project Nijmegen
J	Municipality of Delft	Senior policy advisor traffic and transport
K	Municipality of Schiedam	Senior policy advisor mobility
L	Hely	Commercial director
M	Cargoroo	Co-founder

7.1.2. Interview guide

As described earlier, the objective of these interviews is to gather stakeholder's perceptions on the usage and effects of the existing mobility hubs. As the hubs are relatively new, and it may be difficult to discuss the actual usage and effects, also the governance process around the implementation of the mobility hubs is examined.

To ensure that the objectives of the interviews are fulfilled, the same general structure of the interviews is used in each interview and consists of six phases. Table 19 lists these phases and shortly explains the objective of each phase. The complete standard interview guide, including questions, can be found in Appendix G.

Table 19: Phases and objective per phase of expert interviews

	Phase	Objective
1	Introduction of research	Briefing of interviewee on research and interview
2	Participant introduction	Getting insight in interviewee's expertise and involvement with mobility hubs
3	Questions regarding hub(s)/shared vehicles, implementation, and expectations	Gathering information on background hub (program), ambitions for future
4	Questions on effects and usage of hub(s)/shared vehicles	Identifying how the hub is used and possible effects
5	Questions on collaboration between stakeholders, municipality/providers	Getting insight on governance process: (different perspectives of) stakeholders' roles, requirements, and interaction

7.2. Interview results

By applying the data analysis process as described in section 2.4.3, the approved transcripts of the interviews are grouped and categorised to enable drawing conclusions from the obtained qualitative data. The transcripts are not included in this thesis but can be requested from the author.

This section covers the most relevant comments made in the interviews on the various topics discussed and reflects on the difference and similarities between the remarks of the interviewees. The letters H to M are used to refer to the interviewees, as in Table 18. See section 3.3.2 and appendix B for a description of the existing hubs in the four interviewed municipalities and the providers Hely and Cargoroo.

The discussion on the results is split up into five parts. Section 7.2.1 reviews the benefits and goals of mobility hubs, 7.2.2 discussed, where possible, the usage of the mobility hubs and shared mobility. Section 7.2.3 then elaborates on the (perceived) effects of the mobility hubs on the municipal policy goals. Since the mobility hub concept is still in development and no definite insights can be provided on the usage and effects. Also, the different views on collaboration between the public authorities and commercial providers are discussed in section 7.2.4.

7.2.1. Goals

To verify previous statements on the policy goals for mobility hubs, each interviewee is asked to describe the added value of mobility hubs and why the municipality has chosen to accommodate mobility hubs. Just like in the first round of interviews, the mentioned goals for shared mobility and mobility hubs are largely in line with each other, and as expected, corresponding to the identified policy goals for shared mobility and mobility hubs in the municipal policy documents.

The municipal officials [H], [I], [J], [K] talked about the current challenges their city is facing with respect to housing development and that the current mobility pattern has to change to guarantee the accessibility of the city in the future and, in the meantime, to work on climate ambitions and deal with the scarcity of public space. Active, sustainable and space-efficient mobility is required, and shared mobility fits these three aspects very well [I].

7.2.2. Usage

Usage factors

All interviewees talk about the balance between supply and use. Without a sufficient and diverse supply, the shared vehicles will not be used. However, ensuring this desired supply is hard without the guarantee of usage. This delicate balance will be further elaborated in the next section. Apart from that, there are other factors that the interviewees view as critical, which are elaborated on in the following paragraphs.

[I], [K] and [L] mention that (due to the hub-based system), the users are expecting a certain degree of reliability that there is a vehicle available when they need it. This confidence and available information on availability are crucial for usage. When the (potential) users miss out too often, they will stop using the mobility hub. While [I], [J], [K] each mention that proximity to the mobility hub is important in order to convince (new) users, [J], [K], [L] discovered in their evaluation that there are also people using the hub that live in other areas and are apparently willing to travel some distance to the hub.

Furthermore, as in the constructed causal loop diagram (through the variables *pressure on transportation system & available resources*, *parking availability* and *restricted parking)*, parking policy in the neighbourhood is mentioned by [J], [K], [L] as an important factor for the usage of the mobility hub. In addition, [L] explains that the parking costs are even more important than the parking standard in order for high usage. [H] and [L] explain that new hubs are placed in neighbourhoods where the parking pressure is 90% or lower (i.e., on average, 90% of the parking spots are occupied).

Finally, undeniably, the usage costs are decisive in whether people use the mobility hub or not. And even not necessarily the costs themselves, but the communication about the costs is important so that people know what to expect before making the trip [K].

Reflecting on the causal loop diagram, none of the interviewees have specifically mentioned the presence of public transport connections as an influencing factor for mobility hub usage. Although, there is talked about strategic locations and multimodal transport offer.

While not in the scope of this thesis, [J] and [L] specifically express their expectations regarding a higher use of the mobility hub in development areas. When opening a mobility hub in an existing neighbourhood, people are less likely to change their current mobility behaviour. Moving is a life event that makes people consider their mobility behaviour and how this will fit in their new situation, making it more likely to adjust their fixed behaviour pattern, thus leading to a higher potential of a mobility hub and shared mobility in general.

Usage

Every interviewee is asked to, if possible, say something about the current usage of the mobility hubs or shared mobility in general. The provided answers vary in degree of concreteness and available open data to share. Below, every municipality and provider are discussed separately.

<u>Municipality of Amsterdam</u>

Amsterdam has a very large fleet of shared vehicles, from (electric) bicycles to light electric vehicles and cars. There are 700 free-floating electric mopeds (Felyx and Check), 1300 shared bicycles (FlickBike, Donkey Republic, Go About) and 100 cargo bikes (Cargoroo), and at least six carsharing providers, free-floating and station-based (Gemeente Amsterdam, n.d.-b).

Substantively, in the interview with the municipality of Amsterdam, little is revealed on the usage numbers due to the openness of the question posed and the very high supply and the number of providers active in the city. [H] explains that the providers see much potential in the city, and while many services are not profitable at the moment, providers believe they would be in the future. Reviewing some of the existing (Hely) mobility hubs, the municipality only knows that the hubs are well used, and Hely is content with the usage. Most of these hubs are for a closed community, and the residents of the apartments do not or have limited private mobility options and therefore rely on shared mobility.

<u>Municipality of Nijmegen</u>

Recently the eHUBS project team Nijmegen has published an information letter to the council in which, amongst other things, the usage of the shared vehicles in the mobility hubs are discussed. In the usage figures, a few things stand out. Since the opening of the hubs in June 2020, the seasonality and COVID-19 restrictions and lockdown have had a clear effect on the usage. Moreover, especially e-bikes have suffered from theft and vandalism (College van B&W Nijmegen, 2021b). While the usage of the electric Urbee bikes in the first months was steadily growing. Since September 2020, Urbee started to encounter acts of theft and vandalism nationally. As a consequence, the current supply of e-bikes at the eHUBS is limited and therefore, there is not much to conclude regarding the usage of e-bikes at the mobility hubs. While the electric cargo-bikes of Cargoroo clearly show seasonality effects, the usage is steadily growing, and with an additional supply in the summer, the awareness and use are expected to grow even further [I, M]. See Figure 36 for a diagram on usage in 2020.
The usage, as well as registration of new users for the electric Amber cars and one Tesla from Groodmooves is increasing, see Figure 37 and Figure 38 (College van B&W Nijmegen, 2021b)[I].

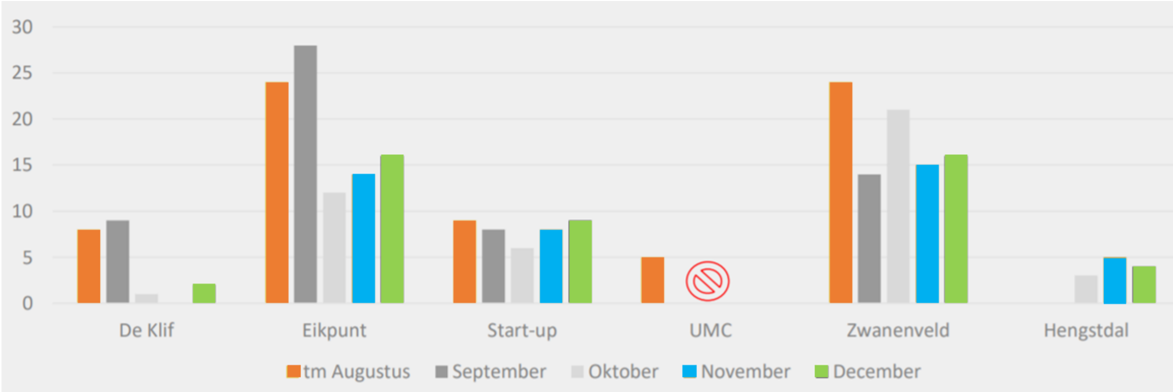


*Figure 36: Number of trips with Cargoroo cargo-bikes per eHUB location from opening in June 2020 to December 2020 (College van B&W Nijmegen, 2021a). *Cargo-bike at UMC in September moved to Hengstdal*

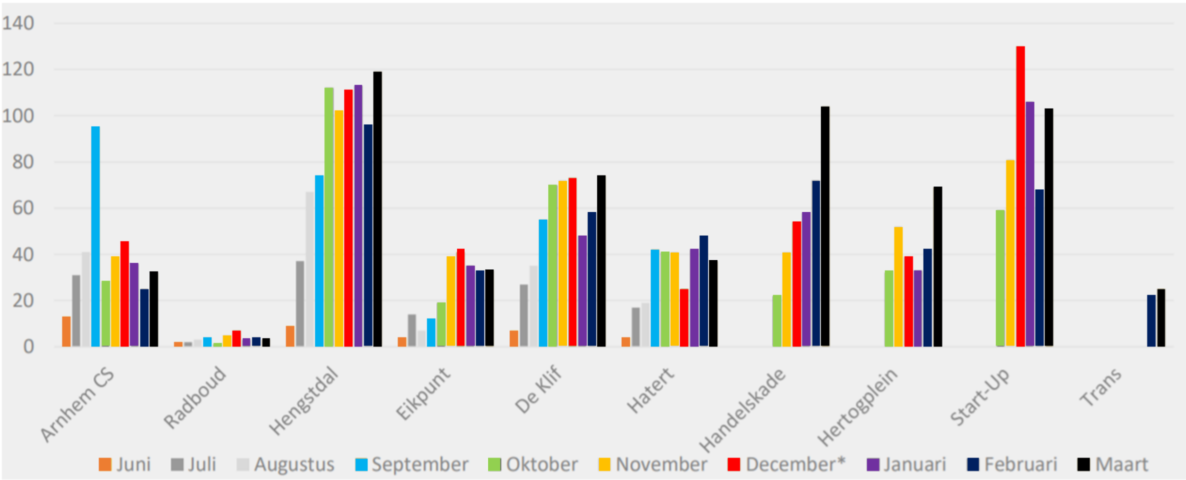


Figure 37: Number of trips with Amber cars per eHUB location from June 2020 to March 2021 (College van B&W Nijmegen, 2021a)

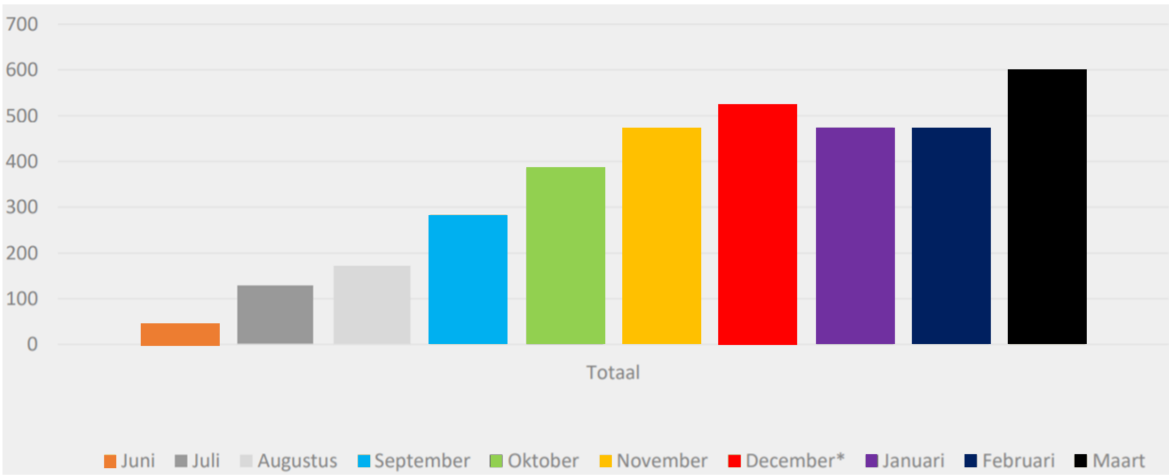


Figure 38: Total number of trips with Amber cars from June 2020 to March 2021 (College van B&W Nijmegen, 2021a)

<u>Municipality of Delft</u>

Interviewee J could not share many figures on the usage of the existing mobility hub in Delft. Instead, refers to Hely's own research after a six-month pilot in the Schoemakers plantage. One of those researches is done by Knippenberg (2019), who has issued a user survey and performed a data analysis from Hely's database for the first 120 operational days of the Hely hub in Delft. Knippenberg describes that there are 113 trips made in the 120-day period, with a lot of users making one trip using a Hely vehicle and only a handful of frequent users. Interestingly, first-time users chose more often for non-car modalities than frequent users (Knippenberg, 2019).

Municipality of Schiedam
[K] explains that the municipality and the shared mobility provider, Juuve, are both content with the usage of the shared vehicles. The usage is steady, and there is hardly a decrease in use due to covid-19. On average, there are 15 to 20 active users per hub (each hub contains two shared cars). Surprisingly, the registered users are not only living in the neighbourhood of the hub but also further away. With respect to the user profile, the average age of the registered users is 35 years old, 60% are men and 40% women. Most users own one or two private cars [K].

Mobility hub provider Hely
Similar to Nijmegen, [L] confirms the seasonal patterns as an influencing factor on the usage of cargo bikes. With the approaching summer and nice weather, the usage grows by 40 to 50%. [L] also confirms the observations of Schiedam [K], that a few mobility hub users are willing to travel a few minutes by bike to reach the mobility hub. Another interesting observation is that the younger the tenants are, the shorter rental periods. There is an almost linear correlation between rental period and age visible.

Shared mobility provider Cargoroo
As electric cargo bikes are especially suited for transporting children or other goods, the average age of users is between 30 and 40 years old (families with children) [M]. Although, there are also a significant number of older users, possibly using the cargo bike for grandchildren. The average rental period is 2-2.5 hours before the bike is returned to its original pick-up location. The average trip length is 10 kilometres [M].

7.2.3. Effects on municipal policy goals

As mobility hubs have not been in operation for that long, and due to the COVID-19 pandemic, most interviewees cannot providence sound evidence for the effects. However, some expectations and preliminary findings are shared in this section.

Municipality of Amsterdam
With respect to the contribution of shared mobility to municipal policy goals, Amsterdam [H] estimates that the free-floating services have no to limited contribution. As most users are young and low car ownership is expected, they generally make extra (car) trips with no influence on car ownership. Besides, many of the carsharing trips are short, between 5 and 10 km. For these distances also other more space-efficient modes are possible.

Some of the existing closed community hubs are estimated to have a positive contribution as the residents are dependent on shared mobility for their movements. As is explained in the governance section (7.2.4), Amsterdam is implementing some cooperative hubs which require commitment from the participants, like giving up their parking permit. This is then also expected to lead to high benefits in terms of private vehicle use and ownership [H].

Municipality of Nijmegen
Interviewee [L] is unable to evaluate the effects of the current eHUBS in Nijmegen. The formal evaluation period for the project starts this coming summer (2021) and will take one year. They see this first year of operations as a start-up phase, and as described in the

previous section, they encountered some issues with theft, vandalism and disappointing usage due to the corona pandemic.

Municipality of Delft

Interviewee [J] at the municipality of Delft does not have up-to-date data from the existing Hely hub but is able to share that six months after the opening of the Schoemaker plantage hub, a few people have stated that they did not buy a car due to the presence of the mobility hub and some people were considering to lower their car ownership. This is confirmed by the study of Van Rooij (2020), who, based on a user survey, indeed concluded that 22% sold a car and 11% did not buy an (extra) car. Also, 6% of the non-users sold a car or did not purchase a car[6]. With respect to car trips, Van Rooij (2020) concludes that the mobility hub has led to an increase in car trips, replacing bike and train trips which is not beneficial for the emission targets.

Municipality of Schiedam

After one year of operations in Schiedam, a small survey is distributed to the hub users, and there is found that on average, two people per mobility hub disposed of their private cars. 55% of the respondents indicated that they use carsharing at the mobility hub as an alternative to a private car [K]. Furthermore, before the shared cars were available, 44% of the users would have made the trip with public transport, another 30% would have used a private car, and 14% uses carsharing instead of a bike or moped [K]. Though it sounds promising that some people sold their private cars as a result of the mobility hub introduction, it is estimated that most of the users do not own a private car (and did not before). The introduction of mobility hubs and carsharing, therefore, probably also leads to increased car usage. This does not immediately contribute to the policy goals as the cars are currently fossil-fuelled cars, but there is the ambition to replace them with electric cars in the future.

Mobility hub provider Hely

Hely mentions that the effect of Hely hubs is difficult to assess because they do not know how people would have travelled if the shared vehicles were not available [L]. They express their doubts on whether, in the end, the effects are positive because they also estimate to attract a lot of users that do not own a private car and now, due to the hub, make 'additional' car trips. Nevertheless, one specific promising case is brought up in the interview. Hely has provided shared bicycles for the Noordwest Ziekenhuisgroep in Alkmaar at five different locations in the city (Hely, n.d.-e). In a few months' time, they realised 10 thousand bike trips. Given that the majority of the employees used to travel by car, these figures are quite promising and illustrate the potential for reducing private car trips [L].

Shared mobility provider Cargoroo

Cargoroo is founded in 2019 to enable people to use an electric cargo bike as a good alternative to a car when having to transport children, groceries or other large goods [M]. In recent user research, 70% has indicated to replace car trips with Cargoroo cargo bikes, which marks a significant reduction.

7.2.4. Governance

As it is impossible to fully evaluate the success of the existing mobility hubs, in the interviews, the different municipalities and providers are asked to reflect on the governance process. Governance is defined as interactions between networks (public and private organisations) caused by the need to exchange resources and negotiate shared purposes (Rhodes, 2007). This section elaborates on the varying opinions and approaches on the development process

[6] These figures are based on Van Rooij's survey sample consisting of 6 mobility hub locations of which Delft Schoemakers plantage accounts for 43.5% of the sample size.

of mobility hubs and the collaboration between stakeholders. See Appendix D for a stakeholder analysis and an initial description of possible roles and interactions. This section further elaborates on these roles and interactions in practice.

Municipality of Amsterdam
Amsterdam knows different applications of shared mobility and varying governance processes. For the implementation of the 'BuurtHubs' within the eHUBS projects, Amsterdam has chosen a bottom-up or participative approach. To make the hub suited to the wishes of the residents, a participation process is set up in which the residents decide on the desired transport modes. Residents within a certain neighbourhood receive a menu with the shared mobility options and can vote for their ideal mobility mix, albeit a combination of shared vehicles or a complete hub concept. This request is then set out for mobility providers to sign up. Residents then collectively take in the mobility supply and can, for example, determine the tariffs themselves. At the moment, one of the obstacles to this cooperative process is that in the current policy, these residents' cooperations are bound to different, more strict regulations, for example, for obtaining a parking permit for the shared car. [H] mentions that this is not quite right as the threshold for commercial parties is much lower while these cooperations generally care more about the perceived contribution to policy goals than the commercial parties that focus on high usage and revenues.

Municipality of Nijmegen
In Nijmegen, every mobility provider is free to express their interest in offering mobility services in the hub. In return, they need to sign a service level agreement and agree to share aggregate data with the municipality and are expected to collaborate in the behavioural change campaign and the marketing campaign. The municipality does not interfere in the business model of the provider but is responsible for providing the required space and facilities in the public space [I].

Municipality of Delft
Interviewee [J] from the municipality of Delft explains that they are still experimenting and learning about the proper roles between the municipality and the providers. For a new mobility hub in Delft, there is chosen for a concession style like in public transport. The municipality and issued a public tender and determined requirements that the providers need to comply with in exchange for financial incentives (Gemeente Delft, 2020). The new mobility hub will be realised in a development area which means that due to limited users, in the beginning, the revenues for the provider will probably not weigh up to the costs. The municipality will contribute to this gap with the idea that it is crucial to have the mobility hub available before the new residents arrive. In order for the new residents to change their mobility behaviour (less private mobility and more shared mobility use), they want certainty regarding the availability of the shared vehicles. Therefore, the municipality has set several requirements, for example, with respect to a minimum availability [J]. All in all, the municipality is quite involved in the governance process of the mobility hubs as they believe it is crucial the lower the threshold for shared mobility and to create an attractive offer.

Municipality of Schiedam
Like Delft, also the municipality of Schiedam is in doubt about the most appropriate role to take. In the pilot phase of the mobility hubs, the municipality has set requirements for the availability, pricing and sharing of aggregate data [K]. With the other shared mobility providers active in the city, the municipality is less involved but thinking about changing its role in order to have more control on the contribution to policy objectives.

Mobility hub provider Hely

Shared mobility provider [L] pleads for less strict requirements from the municipalities and more support in providing access to the public space, providing charging infrastructure and reduced parking permit costs. Interviewee [L] states that the municipalities should make a choice between whether they prefer to regulate shared mobility in a concession (together with requirements and incentives) or leave it completely up to the market. Moreover, the municipality should let project developers more free in the parking standards so that the project developer can for itself determine the required number of parking spots for an apartment building based on his target group and the presence of transport alternatives.

Shared mobility provider Cargoroo

Interviewee [M] comments are in line with [L], and in addition, outlines that these requirements and participative approaches probably stems from uncertainty and fear for resistance and undesired spin-off effects. [M] argues that they are offering municipalities help in achieving their policy objectives. Municipalities should acknowledge this more and subsequently more actively facilitate them.

Location choice

Similarities between the municipalities are visible in regard to the location choice of the mobility hub. All municipalities did appoint approximate locations for the mobility hubs to ensure a spread around the city, considering the characteristics of the neighbourhoods and the current parking pressure [H, I, J, K].

One of the things interviewee [L] mentioned about the future of (Hely) mobility hubs is that "strategically, in the long term we [Hely] do see little future for public neighbourhood mobility hubs". One reason being that [L] does not see added value for a public mobility hub in comparison to free-floating mobility offer. Secondly, the public space is already crowded, and more shared vehicles are therefore not desired. Moreover, by putting a mobility hub in the public space, they become partly dependent on the municipality for several facilities and can, in turn, set high expectations and requirements. Thirdly, a private hub dedicated to a closed community group makes users feel more responsible if it were more their own vehicles. Thus, leading to the hub being more financially profitable [L]. Amsterdam, [H], confirms this expectation and has therefore opted for a very cooperative approach. Nonetheless, [H] does see added value in having (semi-)public mobility hubs in addition to free-floating mobility because both concepts have different target groups.

7.3. Conclusion interview results

Based on the six conducted interviews with municipal officials and shared mobility providers, some insight has been gained with respect to the usage and effects on policy goals. The interviews have also proven to be valuable for making an initial comparison between perspectives on the governance process of mobility hubs.

In short, the interviewees mention there is an increasing trend in usage of neighbourhood mobility hubs, with a relapse due to COVID-19. The perceived effects of the mobility hubs seem to be a declining private car usage and ownership. Additionally, at the moment, there is no proven successful governance. The perception of the six interviewees on the best approach varies. They all stress that they are still in a learning phase.

The remainder of this section further elaborates on the topics of usage, effects and governance and briefly reflects on the established diagram.

7.3.1. Usage

As predicted in chapter 2 Methodology, little quantitative data is available regarding the usage of shared mobility hubs. Also, the interviewees were not able to share many quantitative insights. However, what has become apparent in the interviews is that, in general, over time, the usage of the mobility hubs is increasing. With the exception of a sharp usage decline as a result of COVID-19 measures. In general, the usage figures are promising for the future when more people become familiar with shared mobility and mobility hubs, the number of hubs and interconnectivity (MaaS-applications) are rising.

7.3.2. Effects

The municipal policy goals are things that take time before improvement is measurable. Some preliminary researches, (on the early phases) of mobility hubs, have shown some small but promising effects with respect to private car usage and ownership. However, one could also argue that part of the users indeed uses shared mobility as an alternative to private modes, but also a significant share of uses shared mobility as an addition to their former mobility pattern, which in case of carsharing (as one of the most popular shared modes) leads to extra car trips. Though this not necessarily matches the original policy goals, some interviewees explain that it takes time to let people familiarise themselves and trust shared mobility as a suitable alternative. And in time, when all shared vehicles become zero-emission, it will contribute to both private cars and climate objectives. This phase-wise approach will stimulate the user-uptake for different user groups.

The interviewees estimate the effects of mobility hubs to be larger when the users feel more connected and when there is a sense of responsibility. This will make the users care more about 'their' vehicles, thus less damage, theft, and vandalism. To achieve this community feeling, the hub can either be only accessible for a closed-user group, such as residents of an apartment building or with a very participatory approach that makes the users feel as if the mobility hub implementation is their own project and even are shared owners of the vehicles. Secondly, another perceived high potential situation is when the mobility hubs are located in development areas. Moving to a new home is a life event, and people are more likely to revise and change their mobility behaviour in such circumstances. Thus, at those times, there is a higher potential for reducing private car ownership.

7.3.3. Governance

No definitive answer can be given as to which governance approach is the best. Everyone is still experimenting and trying to learn what works well and whatnot. Besides, governance approaches may vary for different (types of) cities. For example, the demand for shared mobility in Amsterdam is very different to a more rural region or even a smaller city. Table 20 summarised three different governance approaches as discussed in the interviews. A top-down approach means that the public authority is the starting point for the creation of the mobility hub. Residents have little influence on this process. In a bottom-up approach, the focus is more on the stakeholders and collaboration aspect. The process starts on a very local level with the potential users and/or other stakeholders. The role of the local government is to create context and to collecting stakeholders' ideas and initiatives. One step further goes the form of a residents' cooperation where the residents themselves are 'the project managers' and become owners of the project and its assets. Each approach has its own benefits and limitations, as summarised in Table 20.

In addition to the governance process in general, especially in the interviews of [H] and [L], there is talked about in what form shared mobility should be provided. [L] has explained this choice by making a comparison between regulated public transport and commercial airlines. Sole rights with agreements and obligations, or no interference from authorities, and leave it up to the free market. However, solely based on the interviews, no accurate trade-off can be made between these approaches.

Table 20: Advantages and disadvantages of governance approaches for mobility hub implementation

	Advantage	Disadvantage
Top-down	Quick implementation process	Risk of lower usage and decreased effects
Bottom-up (participatory approach)	Commitment and thus higher usage and increased effects	Slow process
Residents' cooperation	Commitment and thus higher usage and increased effects	Policies not suited for this approach, obstacles due to policies and regulations

7.3.4. Reflection on established diagram

The second part of the objective of this interview round was related to reflect on the established diagram and compare the theoretical situation to practice. As explained above, it is not possible (yet) to evaluate the exact usage and usage factors and effects. Due to the novelty and the COVID-19 pandemic. However, some interviewees have shared their thoughts on influencing factors and effects, which have been very useful. The final objectives for mobility hubs, as determined based on policy document analysis, are verified in the interviews. No new factors are mentioned that are not included yet in the final diagram (Figure 34). Based on the interviews conducted, no adjustments need to be made to the diagram.

7.4. Discussion evaluation interviews

In this interview round, six interviews are conducted, of which four are with municipal officials working on mobility hub projects and two shared mobility providers. It cannot be stated that the interviews have reached saturation in the sense that in the final interview, no new insights have been gained. What has become apparent is that, as mentioned by all interviewees, mobility hubs are still a learning object. As they have not existed for that long, no definite conclusion can be drawn with respect to the usage and effectiveness. The provided answers on this topic are, therefore, for a large part based on opinions and own perspectives.

While it would have been possible to conduct additional interviews, saturation probably would not be accomplished because it likely yields more opinions. Besides, as explained in section 7.1.1 about the choices for participant selection, the most relevant parties have already been selected.

Furthermore, just like in the expert interviews, it must be noted that the interviewed experts are potentially biased in the sense that because they are very involved with shared mobility and mobility hubs, they generally tend to be rather positive towards the effects of mobility hubs.

Conclusion, discussion & recommenda-tions

8. Conclusion, discussion & recommendations

In this chapter, the overall conclusions drawn from the research are explained in section 8.1. In the next section (8.2), a discussion is followed regarding the contributions of this research, followed by a reflection on the limitations of the study. The final section (8.3) provides recommendations for further research and recommendations for policymakers regarding the topic of mobility hubs.

8.1. Conclusion research questions

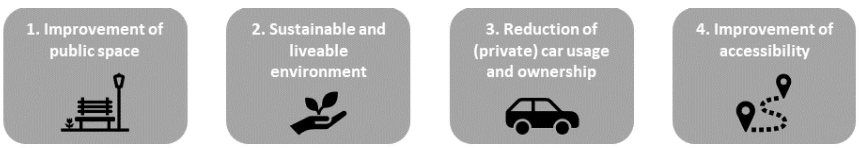
Neighbourhood mobility hubs have been existing for a couple of years. But scientific research and ex-post evaluations into factors influencing the effects, with respect to their policy goals, lacks. This research fills that gap. To answer the central question of this thesis, three sub research questions were formulated. These have been previously answered throughout the report but are united in this section to address the main research question.

In this research, the following definition of a neighbourhood mobility hub is used: a physical location with a catchment area of approximately 500 meters radius, where a variety of shared mobility services are offered. Of which at least one shared car and one shared (e-)bike.

Sub research question 1: What are the municipal policy goals for shared mobility and mobility hubs, and how can a mobility hub be assessed?

With the focus of this thesis being on an ex-post evaluation of existing mobility hubs, it is crucial to set benchmarks and criteria for the evaluation. That is why the first sub research question was aimed at determining how a mobility hub can be assessed and what are the perceived effects. Generally, literature has described promising impacts of shared mobility in terms of the transition to more sustainable urban mobility. To better understand municipalities' perception as a crucial stakeholder with respect to the societal aspect of neighbourhood mobility hubs, a content analysis is done of various Dutch municipal policy documents.

It has become clear that while 'shared mobility' is an often-described subject in municipal policy documents, not always linked to policy goals, and mobility hubs specifically are even covered less often. Of the twenty investigated cities, thirteen had mobility policy documents that mention policy goals for shared mobility. And nine municipalities explicitly mentioned policy goals for mobility hubs. However, mobility hubs can be seen as an enabler of the goals for shared mobility. In conclusion, when shared mobility and mobility hubs are included in policy documents, four main themes are distinguishable:



More tangible: the policy goals in the category of improvement of public space relates to more efficient use of public space and reduction of parking pressure. Moreover, by freeing up space currently used by cars, more space becomes available, which can be transformed into green or seating that improves the quality of the public space or liveability. This is closely related to the category of sustainable and liveable environment, including policy goals with respect to emissions and air quality. The policy theme reduction of (private) car usage and ownership have to do with the desired decline of private vehicles in the cities. The policy goals in the category of improvement of accessibility relate to ensuring the accessibility of certain destinations, and improving public transport connections and/or increasing mobility options for people by providing shared mobility. It is therefore about providing alternatives for conventional travel modes and promoting sustainable and multimodal travel.

Sub research question 2: What are the factors explaining the usage and effects of neighbourhood mobility hubs in literature?

The literature review elaborated on the factors that likely influence the usage, and the effects of mobility hubs. But as the available research is limited, the search is expanded to literature on station-based shared mobility, in the Netherlands or other countries. This literature examined, the conclusion can be drawn that there are a series of influencing factors concerning the usage of different shared modalities and their perceived effects. The review has made clear that all influencing variables and the interconnections make a complex system. Based on the author's interpretation, the most crucial factors and the core of the literature findings are shown in Table 21. The factors and effects are linked to the four policy goals from sub research question 1.

Table 21: Overview of most crucial variables (in random order) and correlations mobility hub usage and effects. Text in orange are the policy goals.

Effect	Factor	Expected impacts (factor → effect)
Mobility hub usage	Accessibility & proximity of mobility hub	+
	Usage costs	-
	Availability of shared vehicles	+
	Size & variety of shared mobility offer	+
	Restricted parking	+
	Private car ownership	-
Usage of shared modalities	Mobility hub usage	+
Private car usage	Usage of shared modalities	-
Private car ownership		-
Vehicle kilometres travelled	Carsharing usage	?
Emissions	Private car usage	+
Private car usage	Private car ownership	+
Parking availability		-
Quality of public space	Parking availability	-

The case of carsharing can illustrate a concrete example of literature findings. Carsharing affects private car usage and ownership, vehicle kilometres travelled, and emissions. More carsharing usage decreases the likelihood of private car usage and the number of private cars owned, and the yearly vehicle kilometres travelled by car. This correlation is, however, dependent on costs variables, the proximity of both the shared and private vehicle. Besides, many personal characteristics are identifiable that influence the likelihood of being a carsharing user, such as the income level, gender, attitude, and level of education. Furthermore, there are several boundary conditions like availability and convenience of using the service. This complex system of influencing variables, interconnections is also present for the other modalities present at the mobility hub (bike, e-bike, e-cargo bike, scooter).

Sub research question 3: To what extent does practice confirm the usage factors and effects, of neighbourhood mobility hubs, obtained from literature research?

The third sub research question is a logical follow-up question for this research. As such, the unified theory of acceptance and use of technology (UTAUT) is used. This theory of behaviour provides a model to assess the likelihood of success for a new technology (i.e. mobility hubs introduction) and understand acceptance drivers. By combining the conceptual framework based on the UTAUT with the literature review, an initial causal loop diagram following the system dynamics approach could be constructed.

The verification is done through a round of expert interviews in which the initial diagram is walked through step by step. They were asked if they recognise the model in practice, and if anything is missing, incorrect, or if there are confusing variables and correlations. This lead to the following conclusions:

The interviewed experts recognise the theory in their practical experiences. While the initial diagram, based on literature, has provided a good insight into the complexity of the mobility hub system. The practice is even more complex. Some suggestions for adjustments to the diagram have been made. The main comments related to:

1. Introduction of categories: level of service, psychological factors, personal characteristics, trip characteristics, built environment characteristics, private car variables. These categories then include several variables that need not be mentioned specifically but are of influence
2. Removal of access & mobility options variable. Though this variable is related to one of the policy goals, some experts expressed their confusion on this variable because the usage of a mobility hub does not lead to more *access & mobility options*, but the presence of a mobility hub itself does.
3. Merger of carsharing and mobility hub variables. The initial CLD treats carsharing variables separately from general mobility hub variables. Because of the large overlap, these variables need to be merged into factors that influence the *mobility hub usage*.

Based on this round of verification, a final version of the causal loop diagram is constructed. This final version is used in the second round of interviews. This provided the last step to arrive at a final conclusion on the main research question.

Main research question: Which factors have influenced the usage and the effects, regarding shared mobility and mobility hub municipal policy goals, of existing neighbourhood mobility hubs?

Based on theory, through literature study, practice, expert and stakeholder interviews, it seemed that there is little knowledge on the influencing factors and effects of neighbourhood mobility hubs. Substantial quantitative data lacks, and also qualitatively, the effects are difficult to identify.

Nevertheless, in the ex-post evaluation interviews, it is discussed that the interviewees, at least, see an increase in mobility hub usage and shared some surveys which indicated promising effects on the societal objectives of mobility hubs, such as a decrease in private car usage and ownership. The other policy goals (emissions, quality of public space and accessibility) are estimated as more indirect consequences of mobility hub usage and not yet evaluable. However, as must also be noted, the effects are not purely positive. There are also negative correlations and consequences possible. Such as, for example, a modal shift towards the car as a result of carsharing. A complete evaluation of the changes and impact in all those variables is not possible yet.

Despite the varying perceptions on usage, effects, and governance. Through expert and stakeholder input and a literature review, a visualisation of the complex system of factors that influence the usage and the effects, regarding shared mobility and mobility hub municipal policy goals of neighbourhood mobility hubs in the Netherlands, can be made. Figure 39 present the answer to the main research question.

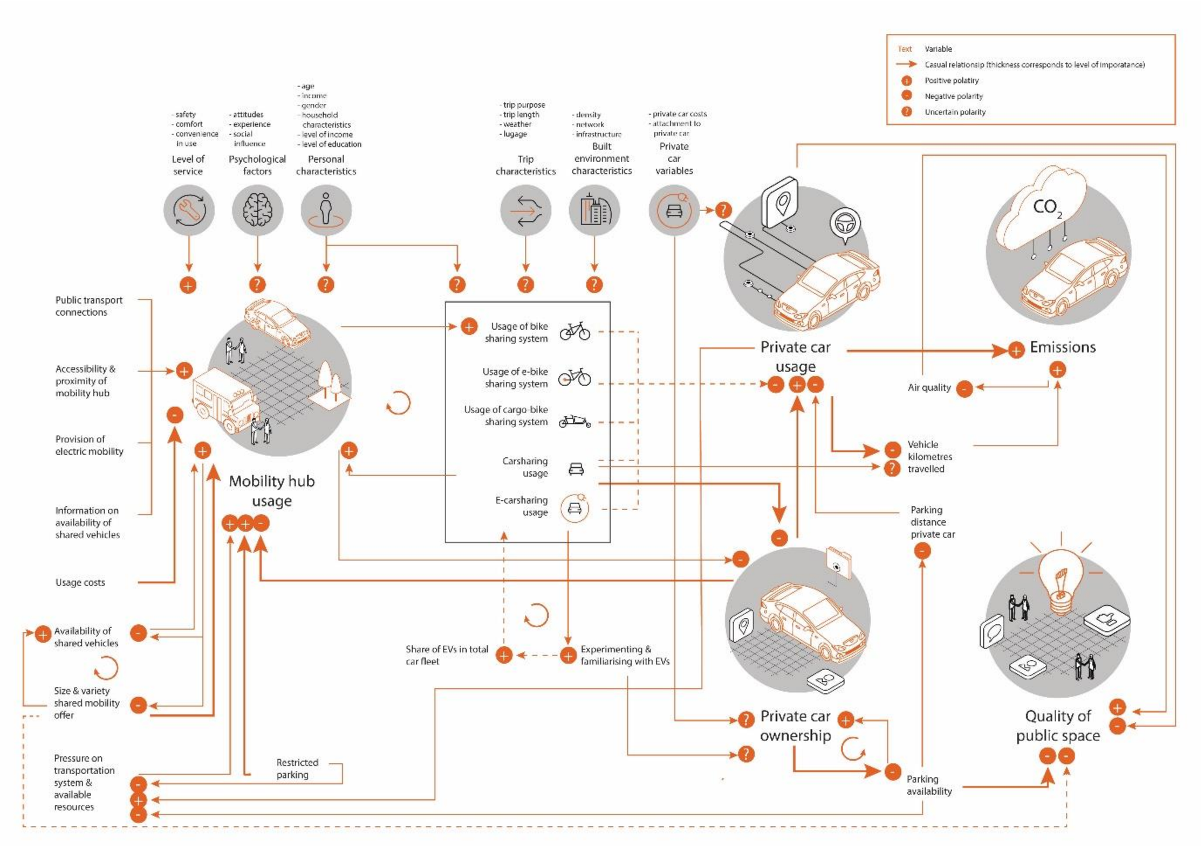


Figure 39: Copy of Figure 34 Final causal loop diagram of neighbourhood mobility hub usage and effects factors

The core of the diagram can be explained as the following: The location (proximity), attributes, mobility supply, contextual factors (parking policy), and user characteristics and perspective influence the usage of the mobility hub and the mode choice within the hub. Using the mobility hub generally decreases private car usage and ownership, which is again related to reduced emissions, freeing up parking space, and improving public space. Though for some users, this may not be necessarily true as they may not decrease their private car usage and ownership and only increase their mobility and travel more vehicle kilometres due to the mobility hub usage. The main take-aways from the model are thus that there are many factors that could influence the usage of a neighbourhood mobility hub. The diagram shows that mobility hub usage could decrease private car usage and ownership, thus indirectly decreasing emissions and improving public space quality. However, the effects are small and still somewhat uncertain. Similarly, the diagram also demonstrates that neighbourhood mobility usage might not contribute to the policy goals. For example, by providing carsharing services, in total, more car trips might be made.

What is not included in this diagram due to the scope, although it is estimated to be of importance, is the location of the mobility hub. It is expected that there is high(er) potential for mobility hubs in development areas in comparison to placing the mobility hub in already existing (residential) areas. Additionally, some interviewees have also suggested that successful mobility hubs' future lies less in the mobility hub in the public space, but more in (completely or partly) closed community groups.

8.2. Discussion

In this section, the results of this thesis are discussed. Firstly, there is elaborated on the contribution of the research, followed by an explanation of the limitations of the research.

8.2.1. Contributions of research

Section 1.6 has discussed the perceived relevance of this research on both a scientific and societal level. In this section, there is reflected on the actual contributions of the research on those two fields.

Scientific

This research has contributed to filling the research gap of adding scientific knowledge on the topic of neighbourhood mobility hubs, and specifically by doing an ex-post evaluation. It is the first research that has conceptually and theoretically analysed a neighbourhood mobility hub.

It has become clear that it is not yet possible to fully map the mobility hub performance yet (within the scope and methodology of this thesis). This has to do with the fact that mobility hubs have not been existing for that long and due to the COVID-19 pandemic the impact. Nevertheless, some small preliminary insights are promising. The interviewed municipalities have stated that a slight decrease in car ownership is visible. Mobility hubs could thus contribute to municipal policy goals to reduce private car usage and ownership, emissions, and create a liveable city. But on the other side, the established diagram also demonstrates that the effect might not be purely positive.

Societal

Regarding the societal interests in neighbourhood mobility hub research, this thesis aimed at two aspects. Namely, providing public and private parties (primarily municipalities and shared mobility providers) with insights on the effects of mobility hubs and whether and to what extent they contribute to certain policy goals. As beforementioned, this research has presented some preliminary insights into the contributions of a mobility hub to municipal policy goals. The second societal objective was to provide guidance in how to implement a successful mobility hub. Through the ex-post evaluation interviews with stakeholders, this has been discussed and evaluated as best as possible, but further research is required for more hard evidence or concrete answers.

Overarching

This research, and in particular the established causal loop diagram depicting the usage factors and effects of neighbourhood mobility hubs, is very valuable for anyone who wants to get started with mobility hubs. It provides guidance on all aspects to consider.

8.2.2. Reflection of findings

Mobility hub definition and categorisation inconclusive

In section 3.1, mobility hubs are categorised into eight categories, and Table 3 displayed amenities belonging to these types of hubs. Reflecting on this by using the literature and interviews, it seems that everyone uses different definitions of mobility hubs. Based on previous researches (see, for example, the comparison between Table 3 and Heller's (2016) research on page 39), users are likely to find mobility hubs with a very complete and diverse mobility offer and services attractive. All in all, the provided categorisation of mobility hubs is quite debatable and subjective.

Findings apply to both neighbourhood mobility hubs and other mobility hubs

In line with the previous comment, no mobility hub is exactly the same. While this research has, where possible, specifically focussed on the neighbourhood type of mobility hub. The author expects that a large part of the findings, including the causal loop diagram, could also be applicable to other types of mobility hubs, like the city(-edge) and regional hubs. The identified usage factors and effects not necessarily only point at local scale factors but can be applied in a general context.

That is the reasons that in this thesis, the word 'mobility hub' is used when actually 'neighbourhood mobility hub' is meant because they are estimated to be useful and equal for both. Moreover, the 'neighbourhood' addition is also left out for the purpose of readability.

Shared mobility policy goals: policy and objectives vs means

Public space plays an important role in the city, it provides a place where people undertake all sort of activities, meets and travel through. A pleasant public space improves the social cohesion and liveability. This is the overarching goal to which mobility policies should comply. There are many measures possible that contribute to this goal. One of them is implementing a mobility hub and developing shared mobility. However, this is not the sole solution. According to the author, what is missing in the policy goals is (1) the coherence between different mobility measures. Think, for example, of shared mobility in combination with a stricter parking policy. And secondly, (2) a critical reflection on any negative side effects has not been disclosed. While in the ex-post evaluation interviews, the interviewees mention that they are still experimenting and learning. This is not so much reflected in their policies.

Secondly, based on the investigated mobility policy documents, it seems that shared mobility and mobility hubs are sometimes seen as a(n) (innovation) goal itself instead. The goal is not to innovate, or implement mobility hubs but to ensure liveability and a good mobility system.

An example of a municipality that acknowledge this and takes a critical approach towards mobility hubs is Groningen. They state: "We will draw up an implementation program for shared mobility in 2021 and one for hubs in 2022. In this, we are focusing on a number of experiments to stimulate shared mobility and to learn how implementation actually contributes to the future in which shared mobility is inextricably linked to the implementation of mobility in everyday life." (Gemeente Groningen, 2021, p. 4)

8.2.3. Limitations of research

This section goes into the limitations of the applied methodology. There are four dominant limitations of this research identifiable.

Qualitative research
Chapter 2 Methodology has explained why there is chosen for this qualitative research approach. In short, quantitative research is not possible yet due to the novelty of the subject. Qualitative research is therefore better suited and fits the objective well. Nevertheless, even a qualitative ex-post evaluation proved more difficult and complex than expected beforehand.

Scope
Section 1.5 has discussed the scope of this research, namely, in short, Dutch neighbourhood mobility hubs and the term *effects* in the various research questions related to the mobility hubs' contribution to municipal policy goals related to the decision for the implementation of a mobility hub. There are three extensions possible to this scope that could have led to additional or different findings.

Although the original scope is narrowed to a specific kind of mobility hub, in the literature review, the search is broadened to shared mobility in general. And also in the interviews some of the comments made (also) apply to other categories of mobility hubs. The author estimates that the research and the established diagram can likely, at least partly, also be applicable to other categories of mobility hubs. While this is not objectionable, at the same time, this cannot be proven.

Secondly, in the ex-post evaluation interviews, other contextual factors are mentioned (such as location choice and moment of opening), that influence the usage of mobility hubs which is due to the scope not being further elaborated on and are not included in the causal loop diagram. Some interviewees, for example, mentioned that they see more potential in placing a mobility hub in a parking garage of an apartment complex or building mobility hubs in new residential development areas. This is an interesting hypothesis to test in the future and might lead to an expansion of the current diagram.

Finally, the research has been limited to exploring the Dutch situation. As a matter of fact, there are several other (European) cities with mobility hubs. In some cases, they have been in operation for longer than the Dutch mobility hubs and could potentially provide additional or alternative insights into usage and effect factors.

Semi-structured interviews
For this research, two rounds of semi-structured interviews are conducted. The first round with mobility experts was aimed to verify the initial causal loop diagram. For this purpose, seven participants were selected from various institutions, aiming at different viewpoints. One can say that this indeed has succeeded because a lot of new insights (suggestions for adjustments) have been gained from the different interviewees (see section 6.4.1). Each participant had their own focus, which made that new insights have been gained even from the seventh interview. This leads to the conclusion that the data collection from the interviews is not necessarily saturated. However, due to the explorative nature of the research, in theory, you could go on much longer. Time restrictions and the author's interpretation of having identified the most critical factors led to the decision of leaving it at seven interviews.

In the second round of interviews, six interviews are conducted. Also, here it is debatable whether full saturation has been achieved. Even though the interviews are conducted with leading organisations and people, the situation is so complex, or the research is conducted in a too early stage that varying opinions have been gathered. Still, for this research, it is decided to leave it at those six interviews because already some very active, different, and yet comparable municipalities were selected. It could be valuable for further research to interview more shared mobility and mobility hub providers (e.g. Juuve, Amber, Mobipunt). Additionally, there are also other municipalities which have not been interviewed yet but do have a mobility hub. The selection of participants for the interviews has been dependent on the desired timeframe of conducting the interviews and the availability of the participants.

Another point of discussion for the interviews of both rounds one and two, is that the interviewees may potentially be biased in the sense that because they are very involved with the topic, they generally tend to be rather positive towards the effects of mobility hubs. Moreover, as shared mobility and mobility hubs are in an early development phase, the current users are the early adopters who may not be necessarily representative for the total population. Thus, it could be the case that at the moment, the effects of mobility hubs are quite positive since early adopters are very concerned with sustainability and reduce their private car usage and ownership, but the early and late majority may only see a mobility hub as an addition to their current mobility options. This is hard to avoid, but more attention could be paid beforehand to selecting interviewees and making sure they have opposing or critical opinions.

Finally, the interviews were conducted in a semi-structured manner. Although interview guides were prepared, the conversation shifted away somewhat in some interviews, which made the interviews' emphasis not always the same in each interview. While this is not necessarily wrong, it may have affected the results. The obtained results may have been slightly different if every interview has strictly discussed every topic in the same level of detail. To avoid this in the future, interview guide can be prepared more thoroughly and should be sticked

Causal loop diagram
As explained in the first two chapters of this thesis, the mobility system is very complex and thus dependent on a large number of factors and relations. Due to the scope and time restrictions, it is impossible to state that the constructed diagram fully captures the system's dynamics. In line with this research's explorative nature, the diagram is still quite aggregate, and the polarity of some correlations is not fixed.

In the causal loop (policy) areas outside of the mobility domain are not considered. Such as aspects in the social, economic, and legal field. While using the constructed causal loop diagram, it must be kept in mind that there are many other influencing factors. Shared mobility is not the only variable affecting private car usage and ownership or the quality of public space.

8.3. Recommendations

This section addresses the recommendations that can be made based on this thesis research. The recommendations consist of two parts. There are possibilities for follow-up research and recommendations to practice. More specifically, for policymakers involved in the topic of mobility hubs.

8.3.1. Recommendations for further research

The recommendations for further research are split up between recommendations that have come forward from literature research, and recommendations based on the obtained results.

Recommendations derived from literature

In the literature review is has become apparent that there is not much scientific literature on neighbourhood mobility hubs. While this thesis contributes to filling that gap, there are still other unexamined parts on the topic. For example, it is remarkable that while, for example, improvement and freeing up public space, is an important policy theme for shared mobility, to the best of the author's knowledge, there is not much scientific literature on shared mobility or even mobility hub impacts and its influence on the public space.

Recommendations derived from findings

As discussed in the conclusion section, there are arguably two causes that make it difficult to answer the main research question with concrete evidence. All things considered, two types of research could provide additional insight into the topic of this thesis.

On the one hand, it would be useful to conduct a similar research again in one or more years' time. Because as the mobility hubs then have been in operation for longer, probably a more specific and reliable conclusion can be drawn with respect to mobility hubs' contribution to (long term) policy goals. The awareness and usage have been given a chance to grow, and possible irregularities can be eliminated from the initial phase. In other words, the Early Adopter phase of mobility hubs is over, the market share has risen. Early adopters are not necessarily representative for the majority of the population. When the market share grows, the identified influencing factors and effects may differ due to changing user characteristics and different perspectives on what users deem important to the service. This follow-up research can be approached qualitatively (interview-based) to verify the variables and correlations of the causal loop diagram. Alternatively, a quantitative study based on data, if available, could also be valuable to objectively substantiate the effectiveness of mobility hubs. The most valuable contribution would be to first look into the modal split changes as a consequence of mobility hubs. *Which modes are replaced by the mobility hub?* Secondly, research should focus on the relation between mobility hubs and private cars. *Does the private car usage and ownership levels change due to the presence of a mobility hub?*

Moreover, in line with the discussion on the societal contribution of this research, at least from practice, there is demand for a further investigation and assessment of mobility hub's governance. Table 20 in section 7.3.3 has given a rough overview of different governance approaches and its advantages and disadvantages. However, that overview is only based on the stakeholder interviews, while there is potential to expand this topic with literature and more interviews. This was not the focus of this research, but as illustrated, there is undoubtedly (societal) interest to further expand the knowledge on this topic.

Additionally, as mentioned in the discussion on the scope of the research, it might be interesting to expand this research internationally. As there are also other European cities with mobility hubs, which in some cases have been in operation longer than the mobility hubs in the Netherlands, lessons could be learned from them. Not only with respect to an evaluation of the effectiveness, but also the different governance approaches are interesting to look at. Another suggestion is to use the established diagram of this study and apply, test and verify it to, for example, the mobility hubs within the European Interreg project.

Another recommendation, which follows from the scope of this research, is to expand the scope to also other categories of mobility hubs and the location of these hubs. As predicted by some interviewees, there is a higher potential for mobility hubs in development areas in comparison to placing the mobility hub in already existing (residential) areas. Additionally, some have also suggested that successful mobility hubs' future lies less in the mobility hub in the public space, but more in (completely or partly) closed community groups. They expect the commitment and reliability of the users to be higher, making the hubs more financially profitable and potentially contribute to a greater extent to the policy goals. It could be valuable to test these two assumptions in future research, for instance, with a research objective to compare differences in a successful implementation of mobility hubs in an existing neighbourhood versus a new neighbourhood. The causal loop diagram can be used as basis or starting point for expansions.

Summary recommendations derived from findings

- ☑ Conduct similar qualitative research again in one or more years' time for validation. Or conduct a quantitative study.
- ☑ Further research mobility hub's governance approaches
- ☑ Expand scope of research internationally
- ☑ Expand scope of research to other types/locations of mobility hubs

8.3.1. Recommendations for policymakers

From the policy document analysis, it has become clear that policies for shared mobility can be linked more explicitly to policy goals so that it is clearer what potential shared mobility/mobility hubs have. This helps to get initiatives, that contribute to one or more of the main societal challenges, off the ground.

In the interviews is discovered that the municipalities are still experimenting and learning about the effectiveness of mobility hubs and the governance process around it. Mobility policies, and potentially the realisation of mobility hub when they serve the mobility policy goals, are system innovations. They have to be collaboratively taken up by municipalities, providers and where possible (future) users. These parties cannot take up the task individually, collaboration and the associated support is required.

Finally, as discussed in section 8.2.2, a recommendation for municipalities is to think about how to make/keep your city liveable. Mobility is an important part of that consideration and there are many solutions possible, all of which cohere. A mobility hub can be measure within the entire package of measures. If you want to implement a (neighbourhood) mobility hub, make use of this thesis and the established diagram because it provides guidance on aspects to consider.

Recommendations for policymakers

- ☑ Link shared mobility/mobility hubs more explicitly to policy goals
- ☑ Consider shared mobility/mobility hubs as one of the measures not a sole solution
- ☑ Be critical and acknowledge the learning process. Collaboration with other municipalities and the providers to find best practices
- ☑ Use the, in this research, established causal loop diagram on influencing factors and effects of neighbourhood mobility hubs when considering the implementation of a mobility hub

Bibliography

Bibliography

Abbas, K. A., & Bell, M. G. H. (1994). System dynamics applicability to transportation modeling. *Transportation Research Part A*, *28*(5), 373–390. https://doi.org/10.1016/0965-8564(94)90022-1

Abduljabbar, R. L., Liyanage, S., & Dia, H. (2021). The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transportation Research Part D: Transport and Environment*, *92*(102734), 1–19. https://doi.org/10.1016/j.trd.2021.102734

Adhabi, E., & Anozie, C. B. (2017). Literature Review for the Type of Interview in Qualitative Research. *International Journal of Education*, *9*(3), 1–12. https://doi.org/10.5296/ije.v9i3.11483

Aguilera-García, Á., Gomez, J., & Sobrino, N. (2020). Exploring the adoption of moped scooter-sharing systems in Spanish urban areas. *Cities*, *96*(102424), 1–13. https://doi.org/10.1016/j.cities.2019.102424

Alarcos Andreu, G. Á. (2017). *Evaluation of the Mobility Station in Domagkpark, Munich - Development and Test of a Methodology for the Impact and Process Evaluation of Sustainable Mobility Measures in the Framework of the ECCENTRIC Project*. TU Munich.

Alberts, G. H. . (2021). *Standing E-scooters, what to expect: mircro-mobility with micro effects?* Delft University of Technology.

Alomary, A., & Woollard, J. (2015). HOW IS TECHNOLOGY ACCEPTED BY USERS? A REVIEW OF TECHNOLOGY ACCEPTANCE MODELS AND THEORIES. *5th International Conference on 4E*, 6.

Amber. (n.d.). *Met 90 locaties altijd een hub bij jou in de buurt| Drive Amber*. Amber Overal in Nederland. Retrieved February 8, 2021, from https://driveamber.com/nl/locaties/

Aono, S. (2019). *Identifying Best Practices for Mobility Hubs Prepared for TransLink*. https://sustain.ubc.ca/sites/default/files/Sustainability Scholars/2018_Sustainability_Scholars/Reports/2018-71 Identifying Best Practices for Mobility Hubs_Aono.pdf

APPM, & Goudappel. (2020). *Gelderse Mobiliteitshubs Cruciale schakels in bereikbaarheid en leefbaarheid.*

Bachand-Marleau, J., Lee, B., & El-Geneidy, A. (2013). Better Understanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use. *Transportation Research Record: Journal of the Transportation Research Board*, *2314*, 66–71. https://doi.org/10.3141/2314-09

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, *15*(2), 73–80. https://doi.org/10.1016/j.tranpol.2007.10.005

Barbour, N., Zhang, Y., & Mannering, F. (2019). A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. *Journal of Transport and Health*, *12*(January), 253–262. https://doi.org/10.1016/j.jth.2019.02.004

Bartsen, C. (2019). *Deelmobiliteit op Strandeiland Een bijdrage aan de emissievrije ambitie* (Issue november). Utrecht University.

Becker, H., Ciari, F., & Axhausen, K. W. (2017). Comparing car-sharing schemes in Switzerland: User groups and usage patterns. *Transportation Research Part A: Policy and Practice*, *97*, 17–29. https://doi.org/10.1016/j.tra.2017.01.004

Becker, H., Ciari, F., & Axhausen, K. W. (2018). Measuring the car ownership impact of free-floating car-sharing – A case study in Basel, Switzerland. *Transportation Research Part D: Transport and Environment*, *65*(August), 51–62. https://doi.org/10.1016/j.trd.2018.08.003

Becker, S., & Rudolf, C. (2018). Exploring the potential of free cargo-bikesharing for sustainable mobility. *GAIA*, *27*(1), 156–164. https://doi.org/10.14512/gaia.27.1.11

Bell, D. (2019). Intermodal mobility hubs and user needs. *Social Sciences*, *8*(2). https://doi.org/10.3390/socsci8020065

Benevolo, C., Dameri, R. P., & Auria, B. D. (2016). *Empowering Organizations: Enabling Platforms and Artefacts*. *11*, 315. https://doi.org/10.1007/978-3-319-23784-8

Bertolini, L. (1999). Spatial development patterns and public transport: The application of an analytical model in the Netherlands. *Planning Practice and Research*, *14*(2), 199–210.

https://doi.org/10.1080/02697459915724

Binder, T., Vox, A., Belyazid, S., Haraldsson, H., & Svensson, M. (2004). DEVELOPING SYSTEM DYNAMICS MODELS FROM CAUSAL LOOP DIAGRAMS. *Proceedings of the 22nd International Conference of the System Dynamic Society*, 1–21.

Bogaert, L. (2019). *Startnotitie Beleid Autodelen*.

Boot, R. (2018). Is de elektrische step de volgende revolutie in stedelijke mobiliteit? *Colloquium Vervoersplanologisch Speurwerk, november*, 1–15. https://cvs-congres.nl/e2/site/cvs/custom/site/upload/file/cvs_2018/id_205_rianne_boot_is_de_elektrische_step_de_volgende_revolutie_in_stedelijke_mobiliteit.pdf

Bourne, J. E., Cooper, A. R., Kelly, P., Kinnear, F. J., England, C., Leary, S., & Page, A. (2020). The impact of e-cycling on travel behaviour: A scoping review. *Journal of Transport and Health*, *19*(August), 100910. https://doi.org/10.1016/j.jth.2020.100910

Brooijmans, S. (2020). *The societal feasibility of sustainable mobility hubs: A case study of Rivium on the societal feasibility of a mobipunt from a user and stakeholder perspective*. Delft University of Technology.

Bryson, J. M. (2004). What to do when stakeholders matter: Stakeholder Identificatixon and analysis techniques. *Public Management Review*, *6*(1), 21–53. https://doi.org/10.1080/14719030410001675722

Bucsky, P. (2020). Modal share changes due to COVID-19: The case of Budapest. *Transportation Research Interdisciplinary Perspectives*, *8*. https://doi.org/10.1016/j.trip.2020.100141

BUUR, & The New Drive. (2019). *Vlaamse beleidsvisie mobipunten*. https://routeplan2030.be/wp-content/uploads/2019/03/VBM-RAPP-20190208-rapport-Vlaamse-Beleidsvisie-Mobipunten.pdf

Cairns, S., Behrendt, F., Raffo, D., Beaumont, C., & Kiefer, C. (2017). Electrically-assisted bikes: Potential impacts on travel behaviour. *Transportation Research Part A: Policy and Practice*, *103*, 327–342. https://doi.org/10.1016/j.tra.2017.03.007

Campbell, A. A., Cherry, C. R., Ryerson, M. S., & Yang, X. (2016). Factors influencing the choice of shared bicycles and shared electric bikes in Beijing. *Transportation Research Part C: Emerging Technologies*, *67*, 399–414. https://doi.org/10.1016/j.trc.2016.03.004

Canitez, F., Alpkokin, P., & Kiremitci, S. T. (2020). Sustainable urban mobility in Istanbul: Challenges and prospects. *Case Studies on Transport Policy*, *8*(4), 1148–1157. https://doi.org/10.1016/j.cstp.2020.07.005

CBS. (2021). *Bevolkingsgroei grotere steden stokt door lage immigratie*. https://www.cbs.nl/nl-nl/nieuws/2021/01/bevolkingsgroei-grotere-steden-stokt-door-lage-immigratie

Chen, T. D., & Kockelman, K. M. (2016). Carsharing's life-cycle impacts on energy use and greenhouse gas emissions. *Transportation Research Part D*, *47*, 276–284. https://doi.org/10.1016/j.trd.2016.05.012

Christiansen, P., Engebretsen, Ø., Fearnley, N., & Usterud Hanssen, J. (2017). Parking facilities and the built environment: Impacts on travel behaviour. *Transportation Research Part A: Policy and Practice*, *95*, 198–206. https://doi.org/10.1016/j.tra.2016.10.025

Christoforou, Z., Gioldasis, C., de Bortoli, A., & Seidowsky, R. (2021). Who is using e-scooters and how? Evidence from Paris. *Transportation Research Part D: Transport and Environment*, *92*(102708), 1–15. https://doi.org/10.1016/j.trd.2021.102708

Claasen, Y. (2019). *Potential effects of mobility hubs: Intention to use shared modes and the intention to reduce household car ownership*. University of Twente.

Cohen, A., & Shaheen, S. (2018). Planning for shared mobility. In *APA Planning Advisory Service Reports: Vol. PAS REPORT*. https://doi.org/10.7922/G2NV9GDD

College van B&W Nijmegen. (2021a). *Bijlage gebruikscijfers informatiebrief eHUBS* (pp. 1–10). Gemeente Nijmegen.

College van B&W Nijmegen. (2021b). *Informatiebrief eHUBS* (pp. 1–6).

CoMoUK. (2019). *Mobility Hubs Guidance*. www.como.org.uk

CROW. (2020, March). *Dashboard autodelen - Aanbieders deelauto's*. Dashboard Autodelen. https://www.crow.nl/dashboard-autodelen/home/wat-is-autodelen/aanbieders-deelauto-s de Kruijf, J., Ettema, D., Kamphuis, C. B. M., & Dijst, M. (2018). Evaluation of an incentive program to stimulate the shift from car commuting to e-cycling in the Netherlands. *Journal of Transport and Health*, *10*, 74–83. https://doi.org/10.1016/j.jth.2018.06.003

Deakin, H., & Wakefield, K. (2014). Skype interviewing: reflections of two PhD researchers. *Qualitative Research*, *14*(5), 603–616. https://doi.org/10.1177/1468794113488126

Dhirasasna, N., & Sahin, O. (2019). A Multi-Methodology Approach to Creating a Causal Loop Diagram. *Systems*, *7*(42), 1–36. https://doi.org/10.3390/systems7030042

Dieten, R. (2015). *Identifying preferences regarding carsharing systems*. Eindhoven University of Technology.

Dorner, F., & Berger, M. (2020). Peer-to-Peer Cargo Bike Sharing : Findings from LARA Share project. *Proceedings of 8th Transport Research Arena*, *March*, 1–13.

Eccarius, T., & Lu, C. C. (2020). Adoption intentions for micro-mobility – Insights from electric scooter sharing in Taiwan. *Transportation Research Part D: Transport and Environment*, *84*(April), 102327. https://doi.org/10.1016/j.trd.2020.102327

Eden, C., & Ackermann, F. (1998). *Making Strategy: The Journey of Strategic Management*. SAGE Publications.

eHUB Arnhem. (n.d.). *eHUB Arnhem* . Retrieved February 5, 2021, from https://ehubarnhem.nl/

eHUB Nijmegen. (n.d.). *eHUB Nijmegen*. Retrieved February 5, 2021, from https://ehubnijmegen.nl/

Energieswitch. (n.d.). *Rotterdams Klimaatakkoord Mobiliteit*.

Eren, E., & Uz, V. E. (2020). A review on bike-sharing: The factors affecting bike-sharing demand. *Sustainable Cities and Society*, *54*(101882), 1–12. https://doi.org/10.1016/j.scs.2019.101882

European Commission. (2017). *Sustainable Urban Mobility: European Policy, Practice and Solutions*. https://doi.org/10.2832/51274

Faghih-Imani, A., Eluru, N., El-Geneidy, A. M., Rabbat, M., & Haq, U. (2014). How land-use and urban form impact bicycle flows: Evidence from the bicycle-sharing system (BIXI) in Montreal. *Journal of Transport Geography*, *41*(August 2012), 306–314. https://doi.org/10.1016/j.jtrangeo.2014.01.013

Ferrero, F., Perboli, G., Rosano, M., & Vesco, A. (2018). Car-sharing services: An annotated review. *Sustainable Cities and Society*, *37*(November 2016), 501–518. https://doi.org/10.1016/j.scs.2017.09.020

Fishman, E. (2016). Bikeshare: A Review of Recent Literature. *Transport Reviews*, *36*(1), 92–113. https://doi.org/10.1080/01441647.2015.1033036

Fishman, E., Washington, S., & Haworth, N. (2013). Bike Share: A Synthesis of the Literature. *Transport Reviews*, *33*(2), 148–165. https://doi.org/10.1080/01441647.2013.775612

Fleury, S., Tom, A., Jamet, E., & Colas-Maheux, E. (2017). What drives corporate carsharing acceptance? A French case study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *45*, 218–227. https://doi.org/10.1016/j.trf.2016.12.004

Galletta, A. (2013). *Mastering the Semi-Structured Interview and Beyond: From Research Design to Analysis and Publication* (Volume 18). NYU Press.

Gallo, M., & Marinelli, M. (2020). Sustainable mobility: A review of possible actions and policies. *Sustainability (Switzerland)*, *12*(18). https://doi.org/10.3390/su12187499

Gemeente Almere. (2020). *Mobiliteitsvisie Almere 2020-2030: Verder bouwen op de sterke basis die Almere heeft*.

Gemeente Amsterdam. (n.d.-a). *BuurtHubs*. Smart Mobility. Retrieved February 8, 2021, from https://www.amsterdam.nl/wonen-leefomgeving/innovatie/smart-mobility/buurthubs/

Gemeente Amsterdam. (n.d.-b). *Deelvervoer - Gemeente Amsterdam*. Deelvervoer. Retrieved June 14, 2021, from https://www.amsterdam.nl/deelvervoer/

Gemeente Amsterdam. (n.d.-c). *eHubs: deelvervoer in de buurt*. Smart Mobility. Retrieved February 8, 2021, from https://www.amsterdam.nl/wonen-leefomgeving/innovatie/smart-mobility/ehubs-deelvervoer-buurt/

Gemeente Amsterdam. (2019a). *Agenda Autodelen*. https://www.amsterdam.nl/parkeren-verkeer/parkeren-straat/agenda-autodelen/

Gemeente Amsterdam. (2019b). *Deelmobiliteit, kansen voor de stad: Beleid voor het delen van schone* *vervoermiddelen anders dan de auto*.

Gemeente Amsterdam. (2019c). *Programma Smart Mobility 2019-2025*.

Gemeente Breda. (2020). *Mobiliteitsvisie breda*. https://www.planbreda.nl/concept+mobiliteitsvisie/mobiliteitsvisie+bekijken/HandlerDownloadFiles.ashx?idnv=1815066

Gemeente Delft. (n.d.). *Mobiliteitsprogramma Delft 2040: Ons Delft, duurzaam bereikbaar*.

Gemeente Delft. (2019). *Mobiliteitstransitie*.

Gemeente Delft. (2020). *AANBESTEDINGSLEIDRAAD EUROPESE OPENBARE AANBESTEDING Mobiliteitshub Nieuw Delft* (pp. 1–21).

Gemeente Den Haag. (2020). *Haagse visie Haagse visie Smart Mobility*.

Gemeente Eindhoven. (2019). *Agenda deelmobiliteit* (Issue april).

Gemeente Groningen. (2021). *Groningen Goed op Weg: Naar een leefbare, schone en gezonde gemeente (concept mobiliteitsvisie)* (Issue april).

Gemeente Haarlem. (2021). *Concept mobiliteitsbeleid*.

Gemeente Rotterdam. (n.d.). *Fietskoers 2025: De fiets als hefboom in de Rotterdamse mobiliteitstransitie*.

Gemeente Rotterdam. (2020). *Rotterdamse Mobiliteits Aanpak*.

Gemeente Schiedam. (2020). *Mobiliteitsvisie: Op weg naar de toekomst*. https://doi.org/10.1007/bf03082089

Gemeente Utrecht. (2019). *Monitor mobiliteitsplan 2019: Slimme routes, slim regelen, slim bestemmen*. www.utrecht.nl

Gemeente Utrecht. (2020). *Mobiliteitsplan 2040: Jouw straat en onze stad gezond, aantrekkelijk en bereikbaar voor iedereen* (Issue Inspraakversie november 2020).

Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: Interviews and focus groups. *British Dental Journal*, *204*(6), 291–295. https://doi.org/10.1038/bdj.2008.192

Gota, S., Huizenga, C., Peet, K., Medimorec, N., & Bakker, S. (2019). Decarbonising transport to achieve Paris Agreement targets. *Energy Efficiency*, *12*(2), 363–386. https://doi.org/10.1007/s12053-018-9671-3

Guidon, S., Becker, H., Dediu, H., & Axhausen, K. W. (2019). Electric Bicycle-Sharing: A New Competitor in the Urban Transportation Market? An Empirical Analysis of Transaction Data. *Transportation Research Record*, *2673*(4), 15–26. https://doi.org/10.1177/0361198119836762

Handy, S. L., & Fitch, D. T. (2020). Can an e-bike share system increase awareness and consideration of e-bikes as a commute mode? Results from a natural experiment. *International Journal of Sustainable Transportation*, 1–16. https://doi.org/10.1080/15568318.2020.1847370

He, Y., Song, Z., Liu, Z., & Sze, N. N. (2019). Factors Influencing Electric Bike Share Ridership: Analysis of Park City, Utah. *Transportation Research Record*, *2673*(5), 12–22. https://doi.org/10.1177/0361198119838981

Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by Bicycle: An Overview of the Literature. *Transport Reviews*, *30*(1), 59–96. https://doi.org/10.1080/01441640903187001

Heller, E. (2016). *Evaluation of Mobility Stations in Offenburg: Assessment of Perception and Acceptance of an Integrated Multimodal Mobility Service and Potential Changes on Mobility Behavior*. TU Munich.

Hely. (n.d.-a). *About Hely*. About Hely. Retrieved February 8, 2021, from https://hely.com/about-hely?lng=en

Hely. (n.d.-b). *Hely: overzicht | LinkedIn*. Hely LinkedIn Company Profile. Retrieved February 9, 2021, from https://www.linkedin.com/company/hely-nl/

Hely. (n.d.-c). *Hely | Al je deelvervoer in één app | Deelauto's, e-bikes & bakfietsen*. Hely Homepagina. Retrieved February 9, 2021, from https://hely.com/?lng=nl

Hely. (n.d.-d). *Hely | Facebook*. Hely Facebook Company Profile. Retrieved February 9, 2021, from https://www.facebook.com/ikwilhely/

Hely. (n.d.-e). *Hely hub NWZ*. Retrieved June 11, 2021, from https://www.hely.com/nwz

Hess, A. K., & Schubert, I. (2019). Functional perceptions, barriers, and demographics concerning e-cargo bike sharing in Switzerland. *Transportation Research Part D: Transport and Environment*, *71*(June 2018), 153–168. https://doi.org/10.1016/j.trd.2018.12.013

Hollingsworth, J., Copeland, B., & Johnson, J. X. (2019). Are e-scooters polluters? the environmental impacts of shared dockless electric scooters. *Environmental Research Letters*, *14*(084031), 1–11. https://doi.org/10.1088/1748-9326/ab2da8

Holm Møller, T., Simlett, J., & Mugnier, E. (2020). Micromobility: Moving cities into a sustainable future. In *Ernst & Young*. https://assets.ey.com/content/dam/ey-sites/ey-com/no_no/news/news-2020/pdf/ey-voi-urbanmobility.pdf

Howe, E., & Jakobsen, F. J. (2020). *unu Global Moped Sharing Market Report 2020*. https://mopedsharing.com/moped-sharing-report

Hull, A. (2008). Policy integration: What will it take to achieve more sustainable transport solutions in cities? *Transport Policy*, *15*(2), 94–103. https://doi.org/10.1016/j.tranpol.2007.10.004

Interreg. (n.d.). *eHUBS - Smart Shared Green Mobility Hubs*. Interreg North-West Europe EHUBS. Retrieved February 5, 2021, from https://www.nweurope.eu/projects/project-search/ehubs-smart-shared-green-mobility-hubs/#tab-1

Jahanshahi, D., Tabibi, Z., & van Wee, B. (2020). Factors influencing the acceptance and use of a bicycle sharing system: Applying an extended Unified Theory of Acceptance and Use of Technology (UTAUT). *Case Studies on Transport Policy*, *8*(4), 1212–1223. https://doi.org/10.1016/j.cstp.2020.08.002

Jittrapirom, P., Caiati, V., Feneri, A. M., Ebrahimigharehbaghi, S., Alonso-González, M. J., & Narayan, J. (2017). Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges. *Urban Planning*, *2*(2), 13–25. https://doi.org/10.17645/up.v2i2.931

Jones, P., Anciaes, P., Buckingham, C., Cavoli, C., Cohen, T., Cristea, L., & Gerike, R. (2018). *Urban Mobility: Preparing for the Future , Learning from the Past*.

Jung, J., & Koo, Y. (2018). Analyzing the effects of car sharing services on the reduction of greenhouse gas (GHG) emissions. *Sustainability (Switzerland)*, *10*(2), 1–17. https://doi.org/10.3390/su10020539

Juuve. (n.d.). *Juuve | Beter dan een eigen auto - Rij direct met de Juuve app. Juuve*. Juuve. Retrieved February 8, 2021, from https://juuve.nl/

Juuve. (2021, June 1). *Juuve & MyWheels gaan samen!* Juuve & Mywheels. https://www.mywheels.juuve.nl/?gclid=Cj0KCQjwxJqHBhC4ARIsAChq4aslJxRVpoaLp53O6a8FL4nDeVYFyLW4Jbx6LOzlv9pdnnJ2-n9FxyIaAoX_EALw_wcB

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, *72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Kaur, K., & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management - JET-M*, *48*(April), 87–96. https://doi.org/10.1016/j.jengtecman.2018.04.006

Kiba-Janiak, M., & Witkowski, J. (2019). Sustainable urban mobility plans: How do they work? *Sustainability (Switzerland)*, *11*(17). https://doi.org/10.3390/su11174605

Knippenberg, K. I. (2019). *Investigation of travel behaviour on a multimodal Mobility-as-a-Service hub within a closed-user area*. Delft University of Technology.

Kwantes, C., Juffermans, N., & Scheltes, A. (2019). HUB's: van hippe hype-fase naar duurzame mobiliteitstransitie. *Colloquium Vervoersplanologisch Speurwerk*, 1–13.

Kwantes, C., van der Linde, L., & Juffermans, N. (2020). De mobiliteitshub : van houtkoolschets naar foto. *Nationaal Verkeerskundecongres*, 1–11.

Laa, B., & Leth, U. (2020). Survey of E-scooter users in Vienna: Who they are and how they ride. *Journal of Transport Geography*, *89*(January), 102874. https://doi.org/10.1016/j.jtrangeo.2020.102874

Liao, F., & Correia, G. (2020). Electric carsharing and micromobility: A literature review on their usage pattern, demand, and potential impacts. *International Journal of Sustainable Transportation*, 1–30. https://doi.org/10.1080/15568318.2020.1861394

Liao, F., Molin, E., Timmermans, H., & van Wee, B. (2020). Carsharing: the impact of system characteristics on its potential to replace private car trips and reduce car ownership. *Transportation*, *47*(2), 935–

970. https://doi.org/10.1007/s11116-018-9929-9

Luginger, L. (2016). *Success Factors of Integrated Multimodal Mobility Service*. TU Munich.

Luna, T. F., Uriona-Maldonado, M., Silva, M. E., & Vaz, C. R. (2020). The influence of e-carsharing schemes on electric vehicle adoption and carbon emissions: An emerging economy study. *Transportation Research Part D: Transport and Environment*, *79*(102226), 1–14. https://doi.org/10.1016/j.trd.2020.102226

Luo, L., & Wildemurth, B. M. (2016). Semistructurerd interviews. In B. M. Wildemuth (Ed.), *Applications of Social Research Methods to Questions in Information and Library Science* (2nd ed., pp. 248–257). ABC-CLIO.

Ma, X., Yuan, Y., Van Oort, N., & Hoogendoorn, S. (2020). Bike-sharing systems' impact on modal shift: A case study in Delft, the Netherlands. *Journal of Cleaner Production*, *259*, 120846. https://doi.org/10.1016/j.jclepro.2020.120846

Macário, R., & Marques, C. F. (2008). Transferability of sustainable urban mobility measures. *Research in Transportation Economics*, *22*(1), 146–156. https://doi.org/10.1016/j.retrec.2008.05.026

Machado, C. A. S., Hue, N. P. M. de S., Berssaneti, F. T., & Quintanilha, J. A. (2018). An overview of shared mobility. *Sustainability (Switzerland)*, *10*(12), 1–21. https://doi.org/10.3390/su10124342

McQueen, M., MacArthur, J., & Cherry, C. (2020). The E-Bike Potential: Estimating regional e-bike impacts on greenhouse gas emissions. *Transportation Research Part D: Transport and Environment*, *87*(August), 102482. https://doi.org/10.1016/j.trd.2020.102482

Meng, L., Somenahalli, S., & Berry, S. (2020). Policy implementation of multi-modal (shared) mobility: review of a supply-demand value proposition canvas. *Transport Reviews*, *40*(5), 670–684. https://doi.org/10.1080/01441647.2020.1758237

Metrolinx. (2011). *MOBILITY HUB GUIDELINES. For the Greater Toronto and Hamilton Area*. http://www.metrolinx.com/en/ regionalplanning/mobilityhubs/mobility%7B %7Dhubs%7B %7Dguidelines.aspx

Metz, F., & van der Meché, M. (2020). *Mobipunten in de Kop van Noord-Holland*. https://amu.rd.naro.go.jp/

Mil, J. van, Leferink, T. S., Annema, J. A., & Oort, N. Van. (2018). *Insights into factors affecting the combined bicycle-transit mode*. https://nielsvanoort.weblog.tudelft.nl/files/2018/06/Van-Mil-et-al-CASPT-paper-2018.pdf

Mingardo, G., van Wee, B., & Rye, T. (2015). Urban parking policy in Europe: A conceptualization of past and possible future trends. *Transportation Research Part A: Policy and Practice*, *74*, 268–281. https://doi.org/10.1016/j.tra.2015.02.005

Miramontes, M. (2018). Assessment of mobility stations: Success factors and contributions to sustainable urban mobility. In *Department of Civil Geo and Environmental Engineering*. TU Munich.

Miramontes, M., Pfertner, M., & Heller, E. (2019). Contributions of Mobility Stations to sustainable urban mobility - The examples of three German cities. *Transportation Research Procedia*, *41*(2016), 802–806. https://doi.org/10.1016/j.trpro.2019.09.128

Miramontes, M., Pfertner, M., Rayaprolu, H. S., Schreiner, M., & Wulfhorst, G. (2017). Impacts of a multimodal mobility service on travel behavior and preferences: user insights from Munich's first Mobility Station. *Transportation*, *44*(6), 1325–1342. https://doi.org/10.1007/s11116-017-9806-y

MOBIAN. (n.d.). *Locaties | MOBIAN.city*. Onze MOBIHUB Locaties. Retrieved June 14, 2021, from https://nl.mobian.city/locations

MOBIAN. (2021, June 11). MOBIAN introduceert uniek mobiliteits membership-model voor bewoners en bedrijven in Amsterdam. *EMERCE*. https://www.emerce.nl/wire/mobian-introduceert-uniek-mobiliteits-membershipmodel-bewoners-bedrijven-amsterdam

Mobiliteitsalliantie. (2019). *Deltaplan 2030*. https://mobiliteitsalliantie.nl/wp-content/uploads/2019/06/Deltaplan-digi.pdf

Mobiliteitsalliantie. (2020). *Startnotitie Hubs*.

Mobiliteitsplatform. (2021, April 21). Gratis parkeren, maar dan wel op de deelfiets! | Mobiliteitsplatform. *Gratis Parkeren, Maar Dan Wel Op de Deelfiets!* https://www.mobiliteitsplatform.nl/bedrijfsnieuws/gratis-parkeren-maar-dan-wel-op-de-deelfiets

Mobipunt. (n.d.-a). *Mobipunt*. Retrieved February 8, 2021, from https://mobipunt.net/#
Mobipunt. (n.d.-b). *Mobipunten lijst*. Mobipunten Lijst. Retrieved February 9, 2021, from https://mobipunt.net/mobipunten/
Mobipunt. (n.d.-c). *Wat is een mobipunt - Mobipunt*. Retrieved February 18, 2021, from https://mobipunt.net/over-mobipunt/wat-is-een-mobipunt/
Moradi, A., & Vagnoni, E. (2018). A multi-level perspective analysis of urban mobility system dynamics: What are the future transition pathways? *Technological Forecasting and Social Change*, *126*(December 2016), 231–243. https://doi.org/10.1016/j.techfore.2017.09.002
Moreau, H., de Meux, L. de J., Zeller, V., D'Ans, P., Ruwet, C., & Achten, W. M. J. (2020). Dockless e-scooter: A green solution for mobility? Comparative case study between dockless e-scooters, displaced transport, and personal e-scooters. *Sustainability (Switzerland)*, *12*(5). https://doi.org/10.3390/su12051803
Mouw, A. (2020). *Applying the concept of mobility hubs in the context of the Achtersluispolder*. Unversity of Twente.
Münzel, K., Boon, W., Frenken, K., Blomme, J., & van der Linden, D. (2020). Explaining carsharing supply across Western European cities. *International Journal of Sustainable Transportation*, *14*(4), 243–254. https://doi.org/10.1080/15568318.2018.1542756
Münzel, K., Piscicelli, L., Boon, W., & Frenken, K. (2019). Different business models – different users? Uncovering the motives and characteristics of business-to-consumer and peer-to-peer carsharing adopters in The Netherlands. *Transportation Research Part D: Transport and Environment*, *73*(July), 276–306. https://doi.org/10.1016/j.trd.2019.07.001
Nabielek, K., Hamers, D., & Evers, D. (2016). Cities in the Netherlands Cities in the Netherlands Facts and figures on cities and urban areas. In *PBL Netherlands Environmental Assessment Agency*.
Natuur & Milieu. (2020). *Mobiliteitshubs - Maak mobiliteitshubs aantrekkelijk en zorg voor diverse mobiliteit*.
Nijland, H., & van Meerkerk, J. (2017). Mobility and environmental impacts of car sharing in the Netherlands. *Environmental Innovation and Societal Transitions*, *23*, 84–91. https://doi.org/10.1016/j.eist.2017.02.001
Nijmegen, G. (2019). *Ambitiedocument mobiliteit 2019-2030*.
Pangbourne, K., Mladenović, M. N., Stead, D., & Milakis, D. (2020). Questioning mobility as a service: Unanticipated implications for society and governance. *Transportation Research Part A: Policy and Practice*, *131*(July 2018), 35–49. https://doi.org/10.1016/j.tra.2019.09.033
Papanikolaou, D. (2011). A new system dynamics framework for modeling behavior of vehicle sharing systems. *Proceedings of the 2011 Symposium on Simulation for Architecture and Urban Design, Society for Computer Simulation International, Boston, Massachusetts*, 126–133. http://dl.acm.org/citation.cfm?id=2048552
Pfertner, M. (2017). *Evaluation of Mobility Stations in Würzburg - perceptions, awareness, and effects on travel behaviour, car ownership, and CO2 emissions*. TU Munich.
Pinna, F., Masala, F., & Garau, C. (2017). Urban policies and mobility trends in Italian smart cities. *Sustainability (Switzerland)*, *9*(4). https://doi.org/10.3390/su9040494
Pruyt, E. (2013). Small System Dynamics Models for Big Issues: Triple Jump towards Real-World Complexity. In *Systems Approaches to Managing Change: A Practical Guide* (1.0). TU Delft Library.
Reck, D. J., Haitao, H., Guidon, S., & Axhausen, K. W. (2021). Explaining shared micromobility usage, competition and mode choice by modelling empirical data from Zurich, Switzerland. *Transportation Research Part C: Emerging Technologies*, *124*(102947), 1–13. https://doi.org/10.1016/j.trc.2020.102947
reisviahub.nl. (n.d.). *Achtergrond - Reisviahub.nl*. Over Hub. Retrieved February 9, 2021, from https://www.reisviahub.nl/over-hub/
reisviahub. (n.d.). *Overzicht van alle hubs*. Reisviahub.Nl. Retrieved July 12, 2021, from https://www.reisviahub.nl/hubs/
Rhodes, R. A. W. (2007). Understanding governance: Ten years on. *Organization Studies*, *28*(8), 1243–1264. https://doi.org/10.1177/0170840607076586

Ricci, M. (2015). Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Research in Transportation Business and Management*, *15*. https://doi.org/10.1016/j.rtbm.2015.03.003

Rijkswaterstaat. (n.d.). *Factsheet Deelfietssystemen - Duurzame mobiliteit*. Factsheet Deelfietssystemen. Retrieved November 27, 2020, from https://rwsduurzamemobiliteit.nl/kennis-instrumenten/toolbox-slimme-mobiliteit/fiets/factsheet-deelfietssystemen/

Rogers, E. (2003). *Diffusion of Innovations* (5th editio). Free Press.

Roukouni, A., & Correia, G. H. de A. (2020). Evaluation methods for the impacts of shared mobility: Classification and critical review. *Sustainability (Switzerland)*, *12*(24), 1–22. https://doi.org/10.3390/su122410504

Saldaña, J. (2013). The Coding Manual for Qualitative Researchers. In *Qualitative Research in Organizations and Management: An International Journal* (2nd editio, Vol. 12, Issue 2). SAGE Publications.

Salvador, E. D. (2018). *Bike Sharing, Swapfiets and a Sustainable City*. https://www.un.org/sustainabledevelopment/sustainable-

Schreier, H., Grimm, C., Kurz, U., Schwieger, D. . B., Keßler, S., & Möser, D. . G. (2018). *Analysis of the impacts of car-sharing in Bremen, Germany. Final report*. https://northsearegion.eu/media/5724/analysis-of-the-impact-of-car-sharing-in-bremen-2018_team-red_final-report_english_compressed.pdf

SEStran. (2020). *Mobility Hubs: A Strategic Study on the South East of Scotland/SEStran region* (Issue March).

Severengiz, S., Schelte, N., & Bracke, S. (2021). Analysis of the environmental impact of e-scooter sharing services considering product reliability characteristics and durability. *Procedia CIRP*, *96*, 181–188. https://doi.org/10.1016/j.procir.2021.01.072

Shaheen, S., Bansal, A., Chan, N., & Cohen, A. (2017). Mobility and the sharing economy: industry developments and early understanding of impacts. *Low Carbon Mobility for Future Cities: Principles and Applications*, 213–240. https://doi.org/10.1049/pbtr006e_ch10

Shaheen, S., Cohen, A., Chan, N., & Bansal, A. (2020). Sharing strategies: Carsharing, shared micromobility (bikesharing and scooter sharing), transportation network companies, microtransit, and other innovative mobility modes. In *Transportation, Land Use, and Environmental Planning* (pp. 237–262). https://doi.org/10.1016/B978-0-12-815167-9.00013-X

Shaheen, S., Cohen, A., & Farrar, E. (2019). Carsharing's Impact and Future. *Advances in Transport Policy and Planning*, *4*, 87–120. https://doi.org/10.1016/bs.atpp.2019.09.002

Shaheen, S., & Cohen, A. P. (2013). Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends. *International Journal of Sustainable Transportation*, *7*(1), 5–34. https://doi.org/10.1080/15568318.2012.660103

Shaheen, S., Guzman, S., & Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia. *Transportation Research Record: Journal of the Transportation Research Board*, *2143*(No. 2143), 159–167. https://doi.org/10.3141/2143-20

Shams Esfandabadi, Z., Ravina, M., Diana, M., & Zanetti, M. C. (2020). Conceptualizing environmental effects of carsharing services: A system thinking approach. *Science of the Total Environment*, *745*(141169), 1–13. https://doi.org/10.1016/j.scitotenv.2020.141169

SHARE-North. (n.d.). *SHARE-North: Shared Mobility Solutions for a Liveable and Low-Carbon North Sea Region*. Retrieved February 8, 2021, from https://share-north.eu/

Shokouhyar, S., Shokoohyar, S., Sobhani, A., & Gorizi, A. J. (2021). Shared mobility in post-COVID era: New challenges and opportunities. *Sustainable Cities and Society*, *67*(November 2020), 102714. https://doi.org/10.1016/j.scs.2021.102714

Slinger, J., & Kwakkel, J. (2008). Does learning to reflect make better modellers? . *Proceedings of the 2008 International Conference of the System Dynamics Society*, 1–8.

Smith, C. S., & Schwieterman, J. P. (2018). *E-scooter scenarios: Evaluating the Potential Mobility Benefits of Shared Dockless Scooters in Chicago*. https://las.depaul.edu/centers-and-institutes/chaddick-institute-for-metropolitan-development/research-and-publications/Documents/E-

ScooterScenariosMicroMobilityStudy_FINAL_20181212.pdf
Spickermann, A., Grienitz, V., & Von Der Gracht, H. A. (2014). Heading towards a multimodal city of the future: Multi-stakeholder scenarios for urban mobility. *Technological Forecasting and Social Change*, *89*, 201–221. https://doi.org/10.1016/j.techfore.2013.08.036
Sterman, J. D. (2000). *Business dynamics : systems thinking and modeling for a complex world*. Irwin/McGraw-Hill.
Storme, T., Casier, C., Azadi, H., & Witlox, F. (2021). Impact assessments of new mobility services: A critical review. *Sustainability (Switzerland)*, *13*(6), 1–20. https://doi.org/10.3390/su13063074
Sun, Q., Feng, T., Kemperman, A., & Spahn, A. (2020). Modal shift implications of e-bike use in the Netherlands: Moving towards sustainability? *Transportation Research Part D: Transport and Environment*, *78*(December 2019), 102202. https://doi.org/10.1016/j.trd.2019.102202
Teoh, R., Anciaes, P., & Jones, P. (2020). Urban mobility transitions through GDP growth: Policy choices facing cities in developing countries. *Journal of Transport Geography*, *88*(October 2019), 102832. https://doi.org/10.1016/j.jtrangeo.2020.102832
Thies, E. (2020, January 14). Een ritje op de deelscooter, het lijkt ook in Utrecht mogelijk te worden. *AD*. https://www.ad.nl/utrecht/een-ritje-op-de-deelscooter-het-lijkt-ook-in-utrecht-mogelijk-te-worden~abd8e498/
Tippabhatla, R. (2020). *Analysing Mobility Hubs using Microsimulation Travel Demand Model*. Delft University of Technology.
Tuncer, S., & Brown, B. (2020). E-scooters on the Ground: Lessons for Redesigning Urban Micro-Mobility. *Conference on Human Factors in Computing Systems - Proceedings*, 1–14. https://doi.org/10.1145/3313831.3376499
UN. (2019). *World Population Prospects: The 2018 Revision*.
Urban Design Studio. (2017). *Mobility Hubs: A Reader's Guide*.
Utriainen, R., & Pöllänen, M. (2018). Review on mobility as a service in scientific publications. *Research in Transportation Business and Management*, *27*(July), 15–23. https://doi.org/10.1016/j.rtbm.2018.10.005
van Asten, R. (2021). *Nota Smart Mobility Visie Den Haag* (pp. 1–3). https://denhaag.raadsinformatie.nl/document/6070415/2/RIS298818 Gebruik laadpalen elektrische auto%27s Den Haag
van de Laak, B. (2020, March 6). *Verbond kijkt mee naar project met e-steps in stadscentrum Stockholm*. AM Web. https://www.amweb.nl/schade/nieuws/2020/03/verbond-kijkt-mee-naar-project-met-e-steps-in-stadscentrum-stockholm-101121916
van Gerrevink, I. (2019). *The role of dockless shared-bikes in Delft: From a user perspective* [Delft University of Technology]. http://resolver.tudelft.nl/uuid:fc8268c5-f627-447c-95a3-9ea81a4ab4a5
van Gils, L. (2019a). *eHUB technical and functional requirements* (Issue November). http://www.nweurope.eu/projects/project-search/ehubs-smart-
van Gils, L. (2019b). *Joint methodology for eHUBs* (Issue december). http://www.nweurope.eu/projects/project-search/ehubs-smart- shared-green-mobility-hubs/
van Goeverden, K., & Correia, G. (2018). Potential of peer-to-peer bike sharing for relieving bike parking capacity shortage at train stations: An explorative analysis for the Netherlands. *European Journal of Transport and Infrastructure Research*, *18*(4), 457–474. https://doi.org/10.18757/ejtir.2018.18.4.3259
Van Marsbergen, A. M. (2020). *Bicycle sharing programs: a complement or substitute of urban public transport? A case study of a bicycle sharing program in The Hague Bicycle sharing programs: a complement or substitute of urban public transport?* [Delft University of Technology]. http://resolver.tudelft.nl/uuid:e23f1239-ff5e-4d43-9c5f-809e2164ebf3
van Mil, Joeri. (2017). *Influencing station choice of cyclists: An innovative solution to reduce bicycle parking pressure at railway stations* [Delft University of Technology]. https://repository.tudelft.nl/islandora/object/uuid%3A6a9f95f1-0829-404f-852b-f0c7425b24b5
van Rooij, D. M. E. (2020). *Neighbourhood mobility hubs: Exploring the potential users, their perceptions and travel behaviour effects*. Delft University of Technology.
van Waes, A., Farla, J., Frenken, K., de Jong, J. P. J., & Raven, R. (2018). Business model innovation and

socio-technical transitions. A new prospective framework with an application to bike sharing. *Journal of Cleaner Production*, *195*, 1300–1312. https://doi.org/10.1016/j.jclepro.2018.05.223

Varvasovszky, Z., & Brugha, R. (2000). A stakeholder analysis: a review. *Health Policy and Planning*, *15*(3), 338–345. https://doi.org/https://doi.org/10.1093/heapol/15.3.338

Vecchio, P. Del, Secundo, G., Maruccia, Y., & Passiante, G. (2019). A system dynamic approach for the smart mobility of people: Implications in the age of big data. *Technological Forecasting and Social Change*, *149*(March), 119771. https://doi.org/10.1016/j.techfore.2019.119771

Venkatesh, Thong, & Xu. (2012). Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Quarterly*, *36*(1), 157. https://doi.org/10.2307/41410412

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), 425–478. https://www.jstor.org/stable/30036540

Weallwheel. (n.d.). *Deelmobiliteit Breda*.

Wefering, F., Rupprecht, S., Bührmann, S., & Böhler-Baedeker, S. (2014). *Guidelines. Developing and Implementing a Sustainable Urban Mobility Plan*. www.eltis.org/mobility-plans

Wilson, C. (2014). Semi-structured interviews. In *Interview Techniques for UX Practicioners: A User-Centered Design Method* (pp. 23–41). Newnes. https://doi.org/10.1016/b978-0-12-410393-1.00002-8

Wolf, A., & Seebauer, S. (2014). Technology adoption of electric bicycles: A survey among early adopters. *Transportation Research Part A: Policy and Practice*, *69*, 196–211. https://doi.org/10.1016/j.tra.2014.08.007

Wong, Y. Z., Hensher, D. A., & Mulley, C. (2020). Mobility as a service (MaaS): Charting a future context. *Transportation Research Part A: Policy and Practice*, *131*, 5–19. https://doi.org/10.1016/j.tra.2019.09.030

Wu, C., Le Vine, S., Clark, M., Gifford, K., & Polak, J. (2020). Factors associated with round-trip carsharing frequency and driving-mileage impacts in London. *International Journal of Sustainable Transportation*, *14*(3), 177–186. https://doi.org/10.1080/15568318.2018.1538401

Ye, J., Zheng, J., & Yi, F. (2020). A study on users' willingness to accept mobility as a service based on UTAUT model. *Technological Forecasting and Social Change*, *157*(120066), 1–9. https://doi.org/10.1016/j.techfore.2020.120066

Yilmaz, K. (2013). Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education*, *48*(2), 311–325. https://doi.org/10.1111/ejed.12014

Yu, Z., Feng, Z., Jiang, K., Huang, Z., & Yang, Z. (2020). Riding personal mobility vehicles on the road : an analysis of the intentions of Chinese users. *Cognition, Technology & Work*, *22*(4), 801–814. https://doi.org/10.1007/s10111-019-00617-9

Zarabi, Z., Manaugh, K., & Lord, S. (2019). The impacts of residential relocation on commute habits: A qualitative perspective on households' mobility behaviors and strategies. *Travel Behaviour and Society*, *16*, 131–142. https://doi.org/10.1016/j.tbs.2019.05.003

Zhang, Y., & Mi, Z. (2018). Environmental benefits of bike sharing: A big data-based analysis. *Applied Energy*, *220*(March), 296–301. https://doi.org/10.1016/j.apenergy.2018.03.101

Zwikker, R., Revier, E., Shachaf, T., Agliati, S., van Langevelde, C., van de Wall, R., Gerretsen, P., & Soret, L. (2021). *Hubs in bestaande wijken: verkennend onderzoek naar ruimtelijke inpassing en impact*. https://issuu.com/deltametropool/docs/hubs-bestaande-wijken_rapport_issuu

Appendices

Appendices: overview

Appendix A	Scientific paper
Appendix B	Literature search strategies
Appendix C	Active mobility hubs in the Netherlands
Appendix D	Stakeholder analysis
Appendix E	Policy goals analysis
Appendix F	Interview guide expert interviews
Appendix G	Interview guide ex-post mobility hub evaluation interviews

A. Scientific paper

Ex-post evaluation of neighbourhood shared mobility hubs in: A qualitative research on the factors influencing the usage and effects of mobility hubs

I.M. van Gerrevink

Delft University of Technology, Delft, The Netherlands

Abstract

Mobility hubs are a promising concept that has been gaining increased attention. Mobility hubs, a place where several (shared) modalities are combined, are seen as an enabler of shared mobility. Shared mobility and mobility hubs could therefore provide attractive alternatives for private vehicles and contribute to municipal policy goals. Like to create more accessible and liveable cities. This study explores the influencing factors for the usage and effects of neighbourhood mobility hubs through an ex-post evaluation of some already existing neighbourhood mobility hubs in the Netherlands. This is examined in a qualitative manner by employing a literature review, applying qualitative system dynamics methodology and conducting semi-structured interviews. A causal loop diagram is constructed that visualises the complexity of mobility hubs and shows the various factors and relations that influence the usage and effects of mobility hubs. The diagram shows that while there is potential, there is also still uncertainty about the precise effects (such as private car usage and ownership), as they may be either positive or negative. The research has contributed to filling the scientific gap on (neighbourhood) mobility hubs, and by mapping influencing factors and effects, provided a framework for further future evaluation of mobility hubs.

Keywords: Mobility hub, shared mobility, causal loop diagram, ex-post evaluation

1. Introduction

The world's population is steadily increasing, and more specifically, cities are growing extremely by the rising share of people residing in urban areas (UN, 2019). This brings extensive economic activities, leading to multiple problems. Many people living on a small surface area and the emerging awareness and reality of climate change make that changes in the current transport and mobility sector are required (Gota et al., 2019). Therefore, cities are taking several (transport) policy actions to reduce the need to travel, make travel more sustainable or increase efficiency. In that light, one of the promising concepts that have been gaining more attention in recent years is the development of shared mobility. Shared mobility is the short-term use of a shared use of a transportation service on an 'as-needed' basis (Machado et al., 2018; Shaheen et al., 2017). The shared use of a transportation service may reduce the need to own a vehicle, which is not only an environmental burden but also takes up a lot of (public) space (Machado et al., 2018; Nijland & van Meerkerk, 2017). Even more recently, 'mobility hubs' are becoming more popular. A mobility hub is defined as a place where several (shared) modalities are combined. This could range from a station area including access/egress facilities to a small-scale hub with a few shared vehicles offered. The potential of shared mobility and mobility hubs is also acknowledged in the Netherlands, as it is increasingly incorporated in policy plans, and in the last two years, about 150 mobility hubs have started to operate in the Netherlands. Mobility hubs are seen as an important contributor to a new, more sustainable mobility system.

From literature research, it followed that scientific literature regarding mobility hubs is scarce. This is supported by the (limited) existing studies existing on the topic (Aono, 2019; Bell, 2019; Miramontes, 2018; Tippabhatla, 2020). This can be split into three subthemes. Firstly, 1) Though the research is expanding through several student theses and consultancy reports, scientific research on small scale hubs, in this research referred to as neighbourhood mobility hubs, is lacking. 2) The (limited) currently available literature and other studies on neighbourhood mobility hubs are predominantly ex-ante studies, focussing on the potential of the neighbourhood mobility hubs. Albeit already several hubs have opened in the Netherlands, as well as other European cities, there lacks a scientific evaluation of these hubs. An ex-post evaluation is very valuable in testing whether the perceived potential effects indeed actually occur. Moreover, the evaluation is not only a contribution to scientific knowledge but also for parties considering implementing a mobility hub. 3) Previous researches have stated that there is potential to further explore the governance process and government policies of shared mobility and mobility hubs (Aono, 2019; Miramontes, 2018; Roukouni & Correia, 2020).

To evaluate the effectiveness and make recommendations on how to improve the effectiveness in the future, it is important to understand the factors that contribute to, or withhold, these (positive) effects. This research, therefore, aims to answer the research question:

Which factors have influenced the usage and the effects, regarding shared mobility and mobility hub municipal policy goals, of existing neighbourhood mobility hubs?

2. Methodology

For this research, a qualitative and explorative approach is taken to find influencing factors of mobility hub usage and effects. A qualitative approach fits the objective well due to the mobility system's dynamics and complexity and to provide a better high-level understanding of these factors. Besides, quantitative research is estimated to not be feasible and scientifically sound at this moment due to the relative novelty of neighbourhood mobility hubs (in the Netherlands), the unavailability of (open) quantitative data and the uncertain precise impact of the COVID19 pandemic in the field of mobility. The research is largely based on three qualitative research methodologies: literature research, system dynamics and interviews.

First, a literature study is performed to create an in-depth understanding of the problem and define the state of the art of mobility hubs, such as to define and categorise mobility hubs and create an overview of the available literature and existing mobility hubs. To be able to answer the research question and perform the ex-post evaluation, the municipal policy goals for shared mobility and mobility hubs need to be defined. This is done through a content analysis of policy documents of Dutch municipalities that are either one of the largest municipalities and/or have a mobility hub.

The next research step was to examine the factors that explain the usage and effects of neighbourhood mobility hubs through a literature review. First, there is started to specifically look into mobility hub researches. But as these are limited, research has expanded to shared mobility usage and effects in general. Literature is scoped to station-based shared mobility usage factors and impacts on the environment, built environment and travel behaviour.

Subsequently, a system dynamics methodology, as developed by Forrester in 1961, is applied. System dynamics is a tool to analyse and structure complex systems to understand feedback loops, reveal the bigger picture, risks, opportunities, hypotheses, policy variables and structures (Binder et al., 2004; Papanikolaou, 2011; Pruyt, 2013). The qualitative part of system dynamics methodology is used in this research to develop a causal loop diagram (CLD) that visualises these factors, as found in the literature review and the relationships between them.

Finally, the third qualitative research methodology that is used in this study are semi-structured interviews. There are two rounds of semi-structured interviews with two different objectives. The round of interviews is to verify and validate the initial causal loop diagram. Together with experts, it is checked whether the initial framework based on literature is correct and complete and matches the practice. The second round of interviews is to gather stakeholder's perceptions on the effects of the existing mobility hubs of which they are/were involved and evaluate these effects based on the established model.

3. Findings

3.1. Definition and categorisation of mobility hubs

From an investigation on previous research into mobility hubs (both scientific and non-scientific), it became clear that there are a variety of terms and definitions used for the 'mobility hub' concept (Aono, 2019; Claasen, 2019; CoMoUK, 2019; Interreg, n.d.;

Metrolinx, 2011; Miramontes et al., 2017; Mobiliteitsalliantie, 2020; SEStran, 2020; Urban Design Studio, 2017; van Rooij, 2020). What these definitions have in common is that the hubs are described as physical locations or nodes that provides access and transfer options to a variety of different (shared) transport modes (multimodal). Moreover, this comparison again illustrates that hubs can be viewed from different scales and perspectives. In essence, eight different types of mobility hubs can be identified by categorising them on their geographic location and their scale of operation (APPM & Goudappel, 2020; CoMoUK, 2019; Mobiliteitsalliantie, 2020; Natuur & Milieu, 2020; SEStran, 2020; van Rooij, 2020; Zwikker et al., 2021). These are: national hubs, city hubs, city-edge hubs, regional hubs, neighbourhood hubs, business park hubs, logistics hubs, and temporary hubs. Each type of hub also has its own specific required/optional amenities.

Zooming in to the scope and research objective, this research focuses on Dutch neighbourhood mobility hubs. While the attention for neighbourhood mobility hubs is rising, a fixed (scientific) definition is missing. Hence, this research uses the following preliminary definition: *A neighbourhood mobility hub is a physical location with a catchment area of approximately 500 meters radius, where a variety of shared mobility services are offered. Of which at least one shared car and one shared (e-)bike.* The mobility supply is the core of a neighbourhood mobility hub, although its fleet size and the diversity of the supply in the different transport modes can vary per hub. The location of the hub should be in close proximity to the potential users. Research has indicated that the average distance a user is willing to travel to such a neighbourhood mobility hub is a maximum of five hundred meters or within walking distance of five minutes (Bartsen, 2019; Claasen, 2019; Dieten, 2015; Knippenberg, 2019; Natuur & Milieu, 2020; van Rooij, 2020)

3.2. Societal goals and ambitions of mobility hubs

For the execution of the ex-post evaluation of mobility hubs, criteria need to be defined. As described in the methodology, this is done through a content analysis of Dutch policy documents. Shared mobility/mobility hub policies are gathered from the 15 municipalities[7] that, of June 2021, have a mobility hub. Because for some municipalities, no relevant or no recent (not older than 2018) documents are found, the list of municipalities is extended with other cities in the top 10 of largest municipalities[8] (CBS, 2021). From the final 21 documents that followed, statements on policy goals related to shared mobility and mobility hubs have been extracted.

What became clear from this analysis is that while almost all municipalities mention shared mobility as a measure or enabler of the mobility transition, in some policy plans, this is not clearly linked to policy goals. Or sometimes, shared mobility is simply regarded as a trend or goal in itself. Only eight municipalities explicitly mentioned the goals of a mobility hub. The mentioned policy goals of mobility hubs in the municipal documents seem to be often related to *multimodality*. Mobility hubs can play an important role in facilitating or stimulating multimodal trips. As the documents mention, shared mobility can improve the accessibility of public transport and improve the last- and first mile. Mobility hubs, especially, are then a place to facilitate the transfer. As also stated in one of the policy goals, mobility hubs and shared mobility reinforce each other. Therefore, mobility hubs can be viewed as an enabler of the goals set for shared mobility.

In general, the policy goals for shared mobility can be broadly divided into four categories:

- Improvement of public space
- Sustainable and liveable environment
- Reduction of (private) car usage and ownership
- Improvement of accessibility

In this study, these four policy themes are thus seen as the desired effects of mobility hubs and will have an important role in the following literature review, causal loop diagram and the final ex post evaluation.

3.3. Literature on influencing factors and effects of mobility hubs

3.3.1. Mobility hub literature

[7] Arnhem, Nijmegen, Amsterdam, Alkmaar, Delft, Den Haag, Ede, Haarlem, Ede, Rotterdam, Utrecht, Lopik, Schiedam, Hollands Kroon, Den Helder, Schagen

[8] Additional municipalites: Eindhoven, Groningen, Tilburg, Almere, Breda

<u>Usage factors</u>

Miramontes (2018) and Miramontes et al. (2017) have described success factors for the users' acceptance of German mobility hubs. These are the location on public space, fixed location of shared mobility services and spatial concentration of diverse mobility, and electric mobility. Similarly, Van Rooij (2020) identified fourteen important design attributes of a mobility hub: diversity, availability, ease of use, visibility, safety of the hub and vehicles, state of the hub and vehicles, distance to the hub, costs of the hub and vehicle, sustainability of the hub and vehicles and if the hub is part of a network. Mouw (2020) elaborates on this list by reviewing other studies on mobility hubs and carsharing and concludes that the distance to the hub is one of the most important factors. Although included in the list of Van Rooij (2020), the costs are not ranked as the top criterium. Other studies have found the costs to be the second most important factor in the usage of a mobility hub (Bartsen, 2019; Claasen, 2019; Dieten, 2015). Knippenberg's research on motives for Hely hub users found that the main reasons are flexibility and convenience, followed by costs and sustainability (Knippenberg, 2019). Heller (2016) let survey participants (bike and carsharing users) rank the importance of several components of a mobility station in Offenburg, Germany. She concluded that public transport connections, the availability of carsharing and the presence of bike sharing are the three most important amenities (Heller, 2016). Additionally, Miramontes (2018) has identified five contextual factors that might contribute to a successful mobility hub. 1) Pressure on the transportation system and available resources, 2) cultural change, 3) Existing shared mobility services in the surrounding, 4) good public transport supply as the backbone, and 4) favourable political and administrative conditions.

<u>Effects</u>

The available literature findings on the (potential) contribution of mobility hubs to the beforementioned four categories of policy goals are summarised in Table 22 (at the end of the paper). Pfertner (2017) calculated the effects of mobility stations on the total amount of emissions reduced and found that overall emissions are saved due to 1) lower CO_2-emission per vehicle kilometre due to smaller and more efficient vehicles in the carsharing fleet compared to the average private car, and secondly 2) reduced private car ownership and usage leads to fewer kilometres travelled. Several studies have found that using mobility hubs contributes to more multimodal travel behaviour and could replace private car ownership and usage (Claasen, 2019; Heller, 2016; Pfertner, 2017; van Rooij, 2020). On the other hand, mobility hub usage and especially carsharing could also lead to additional car trips (Pfertner, 2017; van Rooij, 2020).

3.3.2. Shared mobility literature

With the greatest body of literature and the shared modality closest related to the policy goals, firstly, the impact of carsharing is investigated. While the magnitude of impacts is not always consistent. Generally speaking, academic and non-academic studies agree upon the following impacts of carsharing (Shaheen et al., 2019), which is elaborated in the following paragraph.

- Reduced private vehicle ownership: sold, delayed or foregone vehicle purchases
- Reduced vehicle kilometres travelled (VKT)
- Reduced fuel consumption and GHG emissions
- Increased use of some alternative transportation modes
- Increased access and mobility for car-free households

Two Dutch studies on carsharing have shown that indeed a significant part of the carsharing users are willing to dispose of a current car or give up the intention to purchase a car when carsharing come available nearby (Liao et al., 2020; Nijland & van Meerkerk, 2017). This is also supported by a study amongst carsharing users in Bremen, Germany, where the car ownership in the group of carsharing users is three times lower than in the control group (Schreier et al., 2018).

The general trend found in the relation between carsharing and VKT is that, on average, carsharing users experience a decrease in VKT, albeit a large variation between users. The observed annual reduction of VKT in several studies can be attributed to a small proportion of the users decreasing their VKT by a large amount and a larger proportion increasing their VKT by a relatively small amount (H. Becker et al., 2017; Wu et al., 2020).

Reduced environmental impact due to carsharing is harder to quantify as it can be a consequence of reduced private car ownership (thus lower pollution from the production phase) (Nijland

& van Meerkerk, 2017), less VKT (Jung & Koo, 2018; Schreier et al., 2018) or new vehicle technologies (Luna et al., 2020; Schreier et al., 2018) or a combination of these factors.

As the second-most important modality at the mobility hub (Heller, 2016), also the influencing factors and effects of bike sharing are studied. Bike sharing is expected to contribute to a 1) reduction in car trips, 2) reduction of CO_2 emissions and improvement of air quality, 3) increasing levels of cycling (health benefits), 4) improvement of accessibility and support of multimodal transport connections, 5) easing of traffic congestion, and 6) enhancement of image and liveability of cities (Barbour et al., 2019; Ricci, 2015; Shaheen et al., 2010; Zhang & Mi, 2018). With respect to this first objective, though it sounds very promising, the effect may be minor (Ma et al., 2020; Ricci, 2015). As e-bikes encourage users to cycle faster and longer distances with less physical effort on a conventional bicycle, there are high hopes that e-bikes can play a role in contributing to better air quality, less air and noise pollution and reduction of traffic congestion (McQueen et al., 2020; Sun et al., 2020). There are currently few studies about e-bike share (He et al., 2019; Liao & Correia, 2020), which makes it hard to assign an exact impact. However, studies on private e-bikes have shown a high substitution rate of private car trips and prove that e-bikes have a stronger effect than traditional bike sharing on substituting private car trips (Bourne et al., 2020; Cairns et al., 2017; de Kruijf et al., 2018). Moreover, the implementation of shared e-bike systems can contribute to the share of (private) e-bikes as a sustainable transport mode in the long term. Shared e-bikes systems have been shown to contribute to an increased awareness of e-bikes and a modest increase in people that consider a (private) e-bike for their commute (Handy & Fitch, 2020). Finally, studies on shared e-cargo-bikes have shown that cargo-bike sharing can significantly contribute to private car use and the associated negative environmental impacts (S. Becker & Rudolf, 2018).

All in all, the literature review has given insight into many factors and different aspects that affect the usage and the impact of shared mobility. The literature review has made clear that all influencing variables and the interconnections make a complex system, which makes it impossible to provide a straightforward, textual answer. Nevertheless, through various scientific papers, insights have been gained in the separate shared modalities and their effects on private car usage and ownership, vehicle kilometres travelled, emissions and the dependent variables on these correlations.

3.4. Causal loop diagram

Next, a causal loop diagram will be constructed. This is done in several steps. Firstly, a conceptual framework is constructed on the effectiveness of a mobility hub based on technology adoption theories. For this framework, the revised unified theory of acceptance and use of technology (UTAUT) model is used, which summarises eight other theories of behaviour (Venkatesh et al., 2012; Yu et al., 2020). This is combined with the findings from the literature review. Subsequently, following the guidelines for constructing CLD, an initial diagram is constructed.
To verify the initial causal loop diagram (that is purely based on literature) and to determine whether the diagram correctly visualises the influencing factors and their interrelations, or if it needs some adjustments or expansions to better match to the practice, a round of expert interviews is conducted. Experts in the field of shared mobility and mobility hubs are selected with different viewpoints from a range of institutions. In the expert interviews, the initial diagram is walked through step by step, and the seven interviewees gave suggestions on missing, incorrect, or confusing variables and correlations. The interviewed experts recognise the theory in their practical experiences. While the initial diagram, based on literature, has provided a good insight into the complexity of the mobility hub system, the practice is even more complex, and some suggestions for expanding the diagram has been made. The main comments related to introducing a categorisation for personal characteristics, psychological factors, more clearly stressing the influence of parking policy on shared/private car usage, and accounting for the relevance of the social aspects of mobility hubs. The final diagram is depicted in Figure 40 at the end of the paper.

3.5. Ex post evaluation of existing mobility hubs

The final step of the research then relates to performing the actual ex-post evaluation and gathering information to answer the main research question. For this purpose, another round of semi-structured interviews is conducted. Participants were selected that are involved with existing mobility hubs in the Netherlands. Four municipalities (Amsterdam, Nijmegen, Delft, Schiedam) are interviewed, and two shared mobility/mobility hub providers (Hely, Cargoroo). In the interviews, three main topics are addressed. First, there is started with gathering information on the background of the mobility hub programs and ambitions for the future. In the second part of the interview, the usage and, as far as known, the effects of the hub is discussed. As the hubs are relatively new, and it may be difficult to discuss the actual usage and effects, also the governance process around the implementation of the mobility hubs is examined.

To summarise, the interviewees shared their opinions and perceptions on the usage and effects. Some could substantiate it with data. But overall, it was not easy for the interviewees to properly evaluate the performance of the mobility hubs because it takes time before changes are measurable, and the hubs have not been existing for that long. Nonetheless, some preliminary studies have shown small but promising effects of mobility hubs with respect to private car usage and ownership. However, one could also argue that part of the users indeed uses shared mobility as an alternative to private modes, but also a significant share of uses shared mobility as an addition to their former mobility pattern. Which, in the case of carsharing (as one of the most popular shared modes), leads to extra car trips. Despite being partly out of scope for this research, the interviewees estimate the effects of mobility hubs to be larger when there is more connection and a sense of responsibility. It will make the users care more about 'their' vehicles, thus less damage, theft, and vandalism. To achieve this community feeling, the hub can either be only accessible for a closed-user group, such as residents of an apartment building or with a very participatory approach that makes the users feel as if the mobility hub implementation is their own project and even are shared owners of the vehicles. Secondly, another perceived high potential situation is when the mobility hubs are located in development areas. Moving to a new home is a life event, and people are more likely to revise and change their mobility behaviour in such circumstances. Thus, at those times, there is a higher potential for reducing private car ownership. Apart from these comments, no new factors are mentioned that are not included yet in the final diagram.

Related to the third objective of the interviews to examine the governance. Every interviewee mentioned that stakeholders are still experimenting and trying to learn what works well and what not. For the currently existing mobility hubs, a variety of governance approaches are used. While Nijmegen chose for a quicker top-down process, Amsterdam uses a bottom-up approach. The latter takes more time but on the other side, possibly leads to more commitment and thus higher usage and increased effects. Altogether, solely based on the interviews, no accurate trade-off can be made between these approaches.

4. Conclusion

This research shows that the mobility hub situation is complex and that there are many different factors and relations that influence the usage and effects of mobility hubs. The ex-post evaluation interviews have indicated the usage of mobility hubs is increasing. Moreover, some preliminary researches, (on the early phases) of mobility hubs, have shown some small but promising effects with respect to private car usage and ownership. However, as must be noted, the effects are not purely positive. There are also negative correlations and consequences possible Such as, for example, a modal shift towards the car as a result of carsharing. A proper evaluation of the changes and impact in all those variables is not possible yet. Nevertheless, the final conclusion can be drawn that Figure 40 visualises the factors that influence the usage and the effects, regarding shared mobility and mobility hub municipal policy goals of neighbourhood mobility hubs.

In brief, amongst other things, the location (proximity), attributes, mobility supply, contextual factors (parking policy), and user characteristics and perspective influence the usage of the mobility hub and the mode choice within the hub. Using the mobility hub generally decreases private car usage and ownership, which is again related to reduced emissions, freeing up parking space and an improvement of mobility space. Though for some users this may not be necessarily true as they may not decrease their private car usage and ownership and only increase their mobility and travel more vehicle kilometres due to the mobility hub usage.

5. Discussion and recommendations

5.1. Discussion

There is a lot of potential for neighbourhood mobility hubs, but conclusive evidence cannot be provided based on the current study. This is due to three main reasons:

- As mobility hubs are a relatively new concept, a proper ex-post evaluation is difficult because most hubs are not in operation for that long. It takes some time before the start-up phase is over, and the hubs are steadily operating (not too many fluctuations in use and steady user group or growth). The complexity in answering the research question is higher than estimated beforehand. Despite having interviewed the leading professionals in the field of mobility hubs, even for them, it is not easy to point out the effects and relationships.
- Two rounds of semi-structured interviews have been conducted, and in both cases, each interviewee had its own focus leading to various new insights. This is probably due to the novelty and complexity of the subject. It is, therefore, questionable whether saturation has been achieved.
- Another point of discussion for the interviews, is that the interviewees may potentially be biased in the sense that because they are very involved with the topic. They generally tend to be rather positive towards the effects of mobility hubs. Moreover, as shared mobility and mobility hubs are in an early development phase, the current users are the early adopters who may not be necessarily representative for the total population.

5.2. Recommendations for further research

To gain more insight into the ex-post evaluation of neighbourhood mobility hubs, the research could be repeated in one or more years' time in a qualitative manner. Or alternatively, a quantitative study based on data, if available, could also be valuable to objectively substantiate the effectiveness of mobility hubs.

Secondly, at least from practice, there is demand for a further investigation and assessment of mobility hub's governance. The interviews have given a rough overview of different governance approaches and its advantages and disadvantages. However, that overview is only based on the stakeholder interviews, while there is potential to expand this topic with literature and more interviews. This was not the focus of this research, but as illustrated, there is undoubtedly (societal) interest to further expand the knowledge on this topic.

Additionally, it might be interesting to expand the scope of this research internationally. As there are also other European cities with mobility hubs, which in some cases have been in operation longer than the mobility hubs in the Netherlands, lessons could be learned from them, or comparisons could be made based on the application of the established diagram.

Another recommendation, which follows from the scope of this research, is to expand the scope to also other categories of mobility hubs and the location of these hubs. As mentioned in section 3.5. of this paper, some interviews have made predictions on a higher potential for mobility hubs in development areas in comparison to placing the mobility hub in already existing (residential) areas or mobility hubs with closed community groups. It could be valuable to test these two assumptions in future research.

5.3. Recommendations for policymakers

From the policy document analysis, it has become clear that policies for shared mobility can be based more on the large policy goals so that it is clearer what potential shared mobility/mobility hubs have. This helps to get initiatives, that contribute to one or more of the main societal challenges, off the ground. In the interviews is discovered that the municipalities are still experimenting and learning about the effectiveness of mobility hubs and the governance process around it. Mobility policies, and potentially the realisation of mobility hub when they serve the mobility policy goals, are system innovations. They have to be collaboratively taken up by municipalities, providers and where possible (future) users. These parties cannot take up the task individually, collaboration and the associated support is required.

At the moment, shared mobility and mobility hubs are sometimes seen as a(n) (innovation) goal itself instead. The goal is not to innovate, or implement mobility hubs but to ensure liveability and a good mobility system. This is something that municipalities should acknowledge.

Table 22: Mobility hub factors and effects with expected impacts. Impact relates positive/negative impact of the factor on the effect.

Effect	Factor	Expected impacts	References
Emissions	Smaller & efficient shared cars	-	(Pfertner, 2017)
	VKT	+	
VKT	Additional trips	+	
	Car ownership	+	(Alarcos Andreu, 2017)
	Offer of alternative modes	-	(Heller, 2016; Pfertner, 2017; van Rooij, 2020)
Additional car trips	Carsharing usage	+	(Pfertner, 2017; van Rooij, 2020)
Multimodal travel behaviour	Mobility hub usage	+	(Miramontes et al., 2017)
Car ownership		-	(Knippenberg, 2019)
	Mobility hub introduction	-	(Alarcos Andreu, 2017; Claasen, 2019)
Modal split change		0	(Alarcos Andreu, 2017)

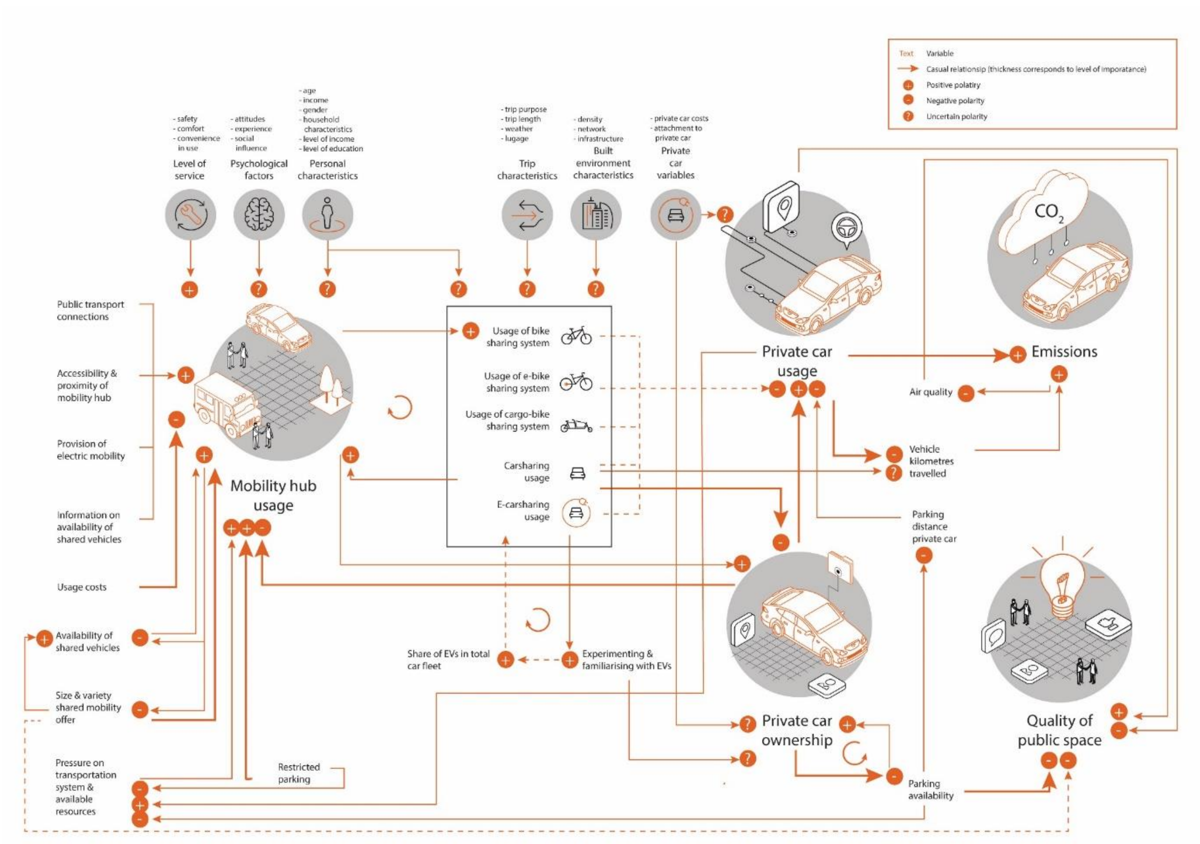


Figure 40: Causal loop diagram mobility hub usage and effects

References

Alarcos Andreu, G. Á. (2017). *Evaluation of the Mobility Station in Domagkpark, Munich - Development and Test of a Methodology for the Impact and Process Evaluation of Sustainable Mobility Measures in the Framework of the ECCENTRIC Project*. TU Munich.

Aono, S. (2019). *Identifying Best Practices for Mobility Hubs Prepared for TransLink*. https://sustain.ubc.ca/sites/default/files/Sustainability Scholars/2018_Sustainability_Scholars/Reports/2018-71 Identifying Best Practices for Mobility Hubs_Aono.pdf

APPM, & Goudappel. (2020). *Gelderse Mobiliteitshubs Cruciale schakels in bereikbaarheid en leefbaarheid*.

Barbour, N., Zhang, Y., & Mannering, F. (2019). A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. *Journal of Transport and Health*, *12*(January), 253–262. https://doi.org/10.1016/j.jth.2019.02.004

Bartsen, C. (2019). *Deelmobiliteit op Strandeiland Een bijdrage aan de emissievrije ambitie* (Issue november). Utrecht University.

Becker, H., Ciari, F., & Axhausen, K. W. (2017). Comparing car-sharing schemes in Switzerland: User groups and usage patterns. *Transportation Research Part A: Policy and Practice*, *97*, 17–29. https://doi.org/10.1016/j.tra.2017.01.004

Becker, S., & Rudolf, C. (2018). Exploring the potential of free cargo-bikesharing for sustainable mobility. *GAIA*, *27*(1), 156–164. https://doi.org/10.14512/gaia.27.1.11

Bell, D. (2019). Intermodal mobility hubs and user needs. *Social Sciences*, *8*(2). https://doi.org/10.3390/socsci8020065

Binder, T., Vox, A., Belyazid, S., Haraldsson, H., & Svensson, M. (2004). DEVELOPING SYSTEM DYNAMICS MODELS FROM CAUSAL LOOP DIAGRAMS. *Proceedings of the 22nd International Conference of the System Dynamic Society*, 1–21.

Bourne, J. E., Cooper, A. R., Kelly, P., Kinnear, F. J., England, C., Leary, S., & Page, A. (2020). The impact of e-cycling on travel behaviour: A scoping review. *Journal of Transport and Health*, *19*(August), 100910. https://doi.org/10.1016/j.jth.2020.100910

Cairns, S., Behrendt, F., Raffo, D., Beaumont, C., & Kiefer, C. (2017). Electrically-assisted bikes: Potential impacts on travel behaviour. *Transportation Research Part A: Policy and Practice*, *103*, 327–342. https://doi.org/10.1016/j.tra.2017.03.007

CBS. (2021). *Bevolkingsgroei grotere steden stokt door lage immigratie*. https://www.cbs.nl/nl-nl/nieuws/2021/01/bevolkingsgroei-grotere-steden-stokt-door-lage-immigratie

Claasen, Y. (2019). *Potential effects of mobility hubs: Intention to use shared modes and the intention to reduce household car ownership*. University of Twente.

CoMoUK. (2019). *Mobility Hubs Guidance*. www.como.org.uk

de Kruijf, J., Ettema, D., Kamphuis, C. B. M., & Dijst, M. (2018). Evaluation of an incentive program to stimulate the shift from car commuting to e-cycling in the Netherlands. *Journal of Transport and Health*, *10*, 74–83. https://doi.org/10.1016/j.jth.2018.06.003

Dieten, R. (2015). *Identifying preferences regarding carsharing systems*. Eindhoven University of Technology.

European Commission. (2017). *Sustainable Urban Mobility: European Policy, Practice and Solutions*. https://doi.org/10.2832/51274

Gota, S., Huizenga, C., Peet, K., Medimorec, N., & Bakker, S. (2019). Decarbonising transport to achieve Paris Agreement targets. *Energy Efficiency*, *12*(2), 363–386. https://doi.org/10.1007/s12053-018-9671-3

Handy, S. L., & Fitch, D. T. (2020). Can an e-bike share system increase awareness and consideration of e-bikes as a commute mode? Results from a natural experiment. *International Journal of Sustainable Transportation*, 1–16. https://doi.org/10.1080/15568318.2020.1847370

He, Y., Song, Z., Liu, Z., & Sze, N. N. (2019). Factors Influencing Electric Bike Share Ridership: Analysis of Park City, Utah. *Transportation Research Record*, *2673*(5), 12–22. https://doi.org/10.1177/0361198119838981

Heller, E. (2016). *Evaluation of Mobility Stations in Offenburg: Assessment of Perception and Acceptance of an Integrated Multimodal Mobility Service and Potential Changes on Mobility Behavior*. TU Munich.

Interreg. (n.d.). *eHUBS - Smart Shared Green Mobility Hubs*. Interreg North-West Europe EHUBS. Retrieved February 5, 2021, from https://www.nweurope.eu/projects/project-search/ehubs-smart-shared-green-mobility-hubs/#tab-1

Jung, J., & Koo, Y. (2018). Analyzing the effects of car sharing services on the reduction of greenhouse gas (GHG) emissions. *Sustainability (Switzerland)*, *10*(2), 1–17. https://doi.org/10.3390/su10020539

Knippenberg, K. I. (2019). *Investigation of travel behaviour on a multimodal Mobility-as-a-Service hub within a closed-user area*. Delft University of Technology.

Liao, F., & Correia, G. (2020). Electric carsharing and micromobility: A literature review on their usage pattern, demand, and potential impacts. *International Journal of Sustainable Transportation*, 1–30. https://doi.org/10.1080/15568318.2020.1861394

Liao, F., Molin, E., Timmermans, H., & van Wee, B. (2020). Carsharing: the impact of system characteristics on its potential to replace private car trips and reduce car ownership. *Transportation*, *47*(2), 935–970. https://doi.org/10.1007/s11116-018-9929-9

Luna, T. F., Uriona-Maldonado, M., Silva, M. E., & Vaz, C. R. (2020). The influence of e-carsharing schemes on electric vehicle adoption and carbon emissions: An emerging economy study. *Transportation Research Part D: Transport and Environment*, *79*(102226), 1–14. https://doi.org/10.1016/j.trd.2020.102226

Ma, X., Yuan, Y., Van Oort, N., & Hoogendoorn, S. (2020). Bike-sharing systems' impact on modal shift: A case study in Delft, the Netherlands. *Journal of Cleaner Production*, *259*, 120846. https://doi.org/10.1016/j.jclepro.2020.120846

Machado, C. A. S., Hue, N. P. M. de S., Berssaneti, F. T., & Quintanilha, J. A. (2018). An overview of shared mobility. *Sustainability (Switzerland)*, *10*(12), 1–21. https://doi.org/10.3390/su10124342

McQueen, M., MacArthur, J., & Cherry, C. (2020). The E-Bike Potential: Estimating regional e-bike impacts on greenhouse gas emissions. *Transportation Research Part D: Transport and Environment*, *87*(August), 102482. https://doi.org/10.1016/j.trd.2020.102482

Metrolinx. (2011). *MOBILITY HUB GUIDELINES. For the Greater Toronto and Hamilton Area*. http://www.metrolinx.com/en/regionalplanning/mobilityhubs/mobility%7B %7Dhubs%7B %7Dguidelines.aspx

Miramontes, M. (2018). Assessment of mobility stations: Success factors and contributions to sustainable urban mobility. In *Department of Civil Geo and Environmental Engineering*. TU Munich.

Miramontes, M., Pfertner, M., Rayaprolu, H. S., Schreiner, M., & Wulfhorst, G. (2017). Impacts of a multimodal mobility service on travel behavior and preferences: user insights from Munich's first Mobility Station. *Transportation*, *44*(6), 1325–1342. https://doi.org/10.1007/s11116-017-9806-y

Mobiliteitsalliantie. (2020). *Startnotitie Hubs*.

Mouw, A. (2020). *Applying the concept of mobility hubs in the context of the Achtersluispolder*. Unversity of Twente.

Natuur & Milieu. (2020). *Mobiliteitshubs - Maak mobiliteitshubs aantrekkelijk en zorg voor diverse mobiliteit*.

Nijland, H., & van Meerkerk, J. (2017). Mobility and environmental impacts of car sharing in the Netherlands. *Environmental Innovation and Societal Transitions*, *23*, 84–91. https://doi.org/10.1016/j.eist.2017.02.001

Papanikolaou, D. (2011). A new system dynamics framework for modeling behavior of vehicle sharing systems. *Proceedings of the 2011 Symposium on Simulation for Architecture and Urban Design, Society for Computer Simulation International, Boston, Massachusetts*, 126–133. http://dl.acm.org/citation.cfm?id=2048552

Pfertner, M. (2017). *Evaluation of Mobility Stations in Würzburg - perceptions, awareness, and effects on travel behaviour, car ownership, and CO2 emissions*. TU Munich.

Pruyt, E. (2013). Small System Dynamics Models for Big Issues: Triple Jump towards Real-World Complexity. In *Systems Approaches to Managing Change: A Practical Guide* (1.0). TU Delft Library.

Ricci, M. (2015). Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Research in Transportation Business and Management*, *15*. https://doi.org/10.1016/j.rtbm.2015.03.003

Roukouni, A., & Correia, G. H. de A. (2020). Evaluation methods for the impacts of shared mobility: Classification and critical review. *Sustainability (Switzerland)*, *12*(24), 1–22. https://doi.org/10.3390/su122410504

Schreier, H., Grimm, C., Kurz, U., Schwieger, D. . B., Keßler, S., & Möser, D. . G. (2018). *Analysis of the impacts of car-sharing in Bremen, Germany.*

Final report. https://northsearegion.eu/media/5724/analysis-of-the-impact-of-car-sharing-in-bremen-2018_team-red_final-report_english_compressed.pdf

SEStran. (2020). *Mobility Hubs: A Strategic Study on the South East of Scotland/SEStran region* (Issue March).

Shaheen, S., Bansal, A., Chan, N., & Cohen, A. (2017). Mobility and the sharing economy: industry developments and early understanding of impacts. *Low Carbon Mobility for Future Cities: Principles and Applications*, 213–240. https://doi.org/10.1049/pbtr006e_ch10

Shaheen, S., Cohen, A., & Farrar, E. (2019). Carsharing's Impact and Future. *Advances in Transport Policy and Planning*, *4*, 87–120. https://doi.org/10.1016/bs.atpp.2019.09.002

Shaheen, S., Guzman, S., & Zhang, H. (2010). Bikesharing in Europe, the Americas, and Asia. *Transportation Research Record: Journal of the Transportation Research Board*, *2143*(No. 2143), 159–167. https://doi.org/10.3141/2143-20

Sun, Q., Feng, T., Kemperman, A., & Spahn, A. (2020). Modal shift implications of e-bike use in the Netherlands: Moving towards sustainability? *Transportation Research Part D: Transport and Environment*, *78*(December 2019), 102202. https://doi.org/10.1016/j.trd.2019.102202

Tippabhatla, R. (2020). *Analysing Mobility Hubs using Microsimulation Travel Demand Model*. Delft University of Technology.

UN. (2019). *World Population Prospects: The 2018 Revision*.

Urban Design Studio. (2017). *Mobility Hubs: A Reader's Guide*.

van Rooij, D. M. E. (2020). *Neighbourhood mobility hubs: Exploring the potential users, their perceptions and travel behaviour effects*. Delft University of Technology.

Venkatesh, Thong, & Xu. (2012). Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Quarterly*, *36*(1), 157. https://doi.org/10.2307/41410412

Wu, C., Le Vine, S., Clark, M., Gifford, K., & Polak, J. (2020). Factors associated with round-trip carsharing frequency and driving-mileage impacts in London. *International Journal of Sustainable Transportation*, *14*(3), 177–186. https://doi.org/10.1080/15568318.2018.1538401

Yu, Z., Feng, Z., Jiang, K., Huang, Z., & Yang, Z. (2020). Riding personal mobility vehicles on the road : an analysis of the intentions of Chinese users. *Cognition, Technology & Work*, *22*(4), 801–814. https://doi.org/10.1007/s10111-019-00617-9

Zhang, Y., & Mi, Z. (2018). Environmental benefits of bike sharing: A big data-based analysis. *Applied Energy*, *220*(March), 296–301. https://doi.org/10.1016/j.apenergy.2018.03.101

Zwikker, R., Revier, E., Shachaf, T., Agliati, S., van Langevelde, C., van de Wall, R., Gerretsen, P., & Soret, L. (2021). *Hubs in bestaande wijken: verkennend onderzoek naar ruimtelijke inpassing en impact*. https://issuu.com/deltametropool/docs/hubs-bestaande-wijken_rapport_issuu

B. Literature search strategies

The following search keys are used in the problem definition of this thesis

Table 23: Search keys and number of results

Search terms	#search results Scopus	Google Scholar	Science Direct
mobility AND hub	780	232 000	22 022
"mobility hub"	20	566	55
neighbourhood AND mobility AND hub	19	23 600	2856
neighbourhood AND "mobility hub"	2	169	32
"neighbourhood mobility hub"	0	0	0
urban "mobility hub"	12	453	45
"mobility hub" AND shared AND mobility	4	447	42
"mobility hub" AND definition	0	435	23
"mobility hub" AND effects	91	396	35
"mobility hub" AND policy	3	426	41
"mobility hub" AND implementation	2	401	44
("multimodal" OR "multi-modal") AND transport* AND hub	250	24 700	2500

C. Existing mobility hubs in the Netherlands

Table 24: eHUBS in Arnhem and Nijmegen (eHUB Arnhem, n.d.; eHUB Nijmegen, n.d.)

Hub name	City	Open since (if known)	Mobility offer[9]	Public or private?
Station Arnhem Centraal	Arnhem	June 2020	cars, e-bikes, (soon cargo-bikes added)	Public
Station Arnhem Zuid	Arnhem	June 2020	e-bikes, cargo-bikes	Public
Transferium Gelredome	Arnhem	June 2020	e-bikes, cargo-bikes	Public
Hatert	Nijmegen	June 2020	1 car, e-bikes	Public
Horstacker (Lindenholt)	Nijmegen	June 2020	e-bikes	Public
Zwanenveld (Dukenburg)	Nijmegen	June 2020	e-bikes, cargo-bikes	Public
Universiteit/Radboud Campus	Nijmegen	June 2020	1 car, cargo-bike	Public
Hengstdal	Nijmegen	June 2020	1 car, e-bike, 1 cargo-bike	Public
Hertogplein	Nijmegen	June 2020	2 cars, e-bike	Public
Station	Nijmegen	June 2020	car, e-bikes, cargo-bikes	Public
Lent (Plantjevlag)	Nijmegen	June 2020	1 car, e-bikes, cargo-bikes	Public
Oosterhout (De Klif)	Nijmegen	June 2020	cars, e-bikes, cargo-bikes	Public
Handelskade	Nijmegen	June 2020	car, e-bikes, cargo-bikes	Public
Frans Halsbuurt	Amsterdam	December 2020	12 e-bikes, 3 cargo-bikes	Public
Hely hub Scoonschip (Buiksloterham)	Amsterdam	December 2020	10 cars, 3 e-bikes, 2 cargo-bikes	Private

Table 25: Mobipunts (Mobipunt, n.d.-b)

Hub name	City	Open since (if known)	Mobility offer	Public or private?
Bergermeer Alkmaar	Alkmaar		2 bikes	Public
Anna Paulowna Station	Anna Paulowna		1 car, 2 bikes	Public
Anna Paulowna Burgemeester Mijnlieffstraat	Anna Paulowna		1 car, 2 bikes	Public
Den Helder Station	Den Helder	July 2020	Soon 2 cars, 4 bikes	Public
Den Helder Zuid	Den Helder	July 2020	2 bikes	Public
Den Helder De Schooten	Den Helder	July 2020	4 bikes	Public
Den Helder Testo	Den Helder	July 2020	3 bikes	Public
Den Oever busstation	Den Oever		4 bikes	Public
Agriport Zuid	Medemblik		2 bikes	Public
Middenmeer	Middenmeer		1 car, 2 bikes	Public
Middenmeer Zuid	Middenmeer		2 bikes	Public
Schagen station	Schagen	July 2020	Soon 4 cars, 3 bikes	Public
Schagen Witte Paal – pro	Schagen		2 cars, 2 bikes	Public
't Veld	't Veld		1 car, 2 bikes	Public
Wieringerwerf	Wieringerwerf		2 bikes	Public

[9] Most e-bikes temporarily removed due to (risk of) vandalism (eHUB Arnhem, n.d.; eHUB Nijmegen, n.d.)

Table 26: Hely hubs (Hely, n.d.-c, n.d.-b, n.d.-d)

Hub name	City	Open since (if known)	Mobility offer	Public or private?
Hely hub Zuidas	Amsterdam	December 2019	2 cars, 4 e-bikes, 1 cargo-bikes	Public
Hely hub Bajeskwartier	Amsterdam	September 2020	2 cars, 2 e-bikes	Public
Hely hub Marineterrein	Amsterdam	?	1 car, 4 e-bikes, 1 cargo-bike	Public
Hely hub Station Zuid	Amsterdam	July 2020	35 e-bikes	Public
Hely hub Schoenmaker plantage	Delft	December 2018	3 cars, 4 e-bikes	Public
Hely hub Binckhorst	Den Haag	May 2019	2 cars, 1 cargo-bike	Public
Hely hub Bezuidenhout	Den Haag	June 2019	1 car, 4 e-bikes, 1 cargo-bike	Public
Hely hub Ede	Ede	September 2020	2 cars, 4 e-bikes, 1 cargo-bike	Public
Hely hub Scheepsmakerswijk	Haarlem	April 2019	2 cars, 4 e-bikes, 1 cargo-bike	Public
Hely hub Nassauhaven	Rotterdam	December 2020	2 cars	Public
Hely hub Rachminoff	Utrecht	April 2020	4 cars, 4 e-bikes	Public
Hely hub Schildersbuurt	Utrecht	June 2019	2 cars, 4 e-bikes	Public
Hely hub Station Brandevoort	Helmond	June 2021	1 car, 2 cargo-bikes	Public
Hely hub Student Experience	Amsterdam	November 2020	2 cars, 100 bikes, 10 e-bikes	Private
Hely hub de Werf	Amsterdam	September 2019	4 cars, 4 e-bikes, 1 cargo-bike	Private
Hely hub OurDomain	Amsterdam (Diemen)	December 2020	8 cars, 5 bikes, 5 e-bikes	Private
Hely hub OurDomain South East	Amsterdam (Diemen)	June 2021	Cars, e-bikes, cargo-bikes	Private
Hely hub CityTwin	Breda	December 2020	3 cars	Private
Hely hub Rivium	Capelle aan den Ijssel	December 2020	2 cars	Private
Hely hub Harvest	Den Haag	December 2020	1 car, 3 e-bikes, 1 cargo-bike	Private
Hely hub MB275	Den Haag	December 2020	2 cars, 4 e-bikes	Private
Hely hub Gorter	Leiden	December 2020	2 cars, 4 bikes, 4 e-bikes	Private
Hely hub Startmotor	Rotterdam	September 2020	2 cars, 4 e-bikes, 1 cargo-bike	Private
Hely hub Canvas	Utrecht	June 2021	2 cars, e-bikes (soon)	Private

Table 27: Juuve hubs (Juuve, n.d.)

Hub name	City	Open since (if known)	Mobility offer	Public or private?
Deelhub Benschop	Benschop	June 2020	2 cars	Public
Deelhub Rembrandtlaan	Schiedam	September 2019	2 cars	Public
Deelhub Westfrankelandsestraat	Schiedam	September 2019	2 cars	Public
Deelhub Dwarsstraat	Schiedam	September 2019	2 cars	Public

Hub name	City	Open since (if known)	Mobility offer	Public or private?
Deelhub Kruising Willemskade	Schiedam	September 2019	2 cars	Public
Deelhub de Grifthoek	Utrecht	February 2020	7 cars, 5 e-bikes, cargo-bikes	Public
Groothandelsgebouw	Rotterdam		2 cars	Private (residents and employees)
Het industriegebouw	Rotterdam		1 car	Private (residents and employees)
Deelhub Timmerhuis	Rotterdam	January 2018	4 cars	Private
VvE Stack Haarlem	Haarlem	May 2018	3 cars	Private
Elsenhouwerlaan	Den Haag		2 cars	Private
Driestraatjes	Naaldwijk		2 cars	Private
City Campus Max	Utrecht		6 cars	Private
Deelhub Noorderhaven	Zutphen		2 cars	Private

D. Stakeholder analysis

A stakeholder analysis is executed to map the stakeholders that play a role in the development and implementation of the mobility hubs concept. This is required for the determination of which actors to interview about the evaluation of existing mobility hubs and to know the interdependencies between actors. For each stakeholder their objectives, problem perception, power and interest are analysed and put in a power versus interest grid. For further elaboration on a stakeholder analysis and methodology, see section 2.3.

D.1. Stakeholder identification

Several parties are involved in the implementation process of a mobility hub. The most important parties are described in this section. Kwantes et al. (2019) describes four possible parties behind the realisation of mobility hubs: (1) Transport authorities. Or in other words, and more specifically applied to neighbourhood mobility hubs, 'public authorities' and then, in particular, the municipalities. (2) Project developers, (3) residents and potential users via bottom-up approaches and (4) logistics parties collaborating on zero-emission city logistics. The latter not being relevant in the realisation of neighbourhood mobility hubs.

Neighbourhood residents

The neighbourhood residents, people living within the service area of the hub, can be further subdivided into actual users of the mobility hub and non-users or potential users.

<u>Users</u>

The users are the key actor as the aim of the mobility hub is to provide the user with mobility options. The main interest of the user is that they can travel whenever and wherever they want with their preferred transport mode for a reasonable price.

<u>Non-users/potential users</u>

The interest of the potential users is similar to the users only that they consider a broader range of transport modes, also including their own private vehicles. The potential users are a larger group than the users itself because it includes everyone living within the service area of the hubs. From previous studies it seemed that a maximum distance a user is willing to travel to a hub is three hundred to five hundred meters, or five minutes walking (Bartsen, 2019; Dieten, 2015; Natuur & Milieu, 2020; van Rooij, 2020). This means that residents living within this range can be classified as the potential users of the hub. For the potential users to become users of the hub several prerequisites have to be met that makes the hub and its shared modes appealing in their travel behaviour choices.

Public authorities

Varying with the scale of mobility hub, governmental institutions have an important role in the implementation of these mobility hubs. Public authority can be seen as one entity, but it also exists of different layers and stakeholders.

- National public authority: Ministry of Infrastructure and Water Management
- Regional public authority: province/metropolitan region and transport authority
- Local public authority: municipality

There are generally two approaches for the implementation of mobility hubs as described in the theoretical framework of the INTERREG eHUBS project description (van Gils, 2019b). There is a distinction between the top-down and a bottom-up approach. A top-down approach starts with a broad vision on mobility and its future development from a higher-level public authority. In a top-down mobility hub approach, the public authority is the starting point of the location selection and configuration of the hub. The existing transportation infrastructure and traffic flows are considered and a number of characteristic layers (networks, parking places, important locations). The planners decide which of these aspects are relevant for the situation and their importance. In a bottom-up approach the focus is more on the stakeholders and collaboration aspect. The process starts on a very local level with initiatives from or in cooperation with the potential users and/or other stakeholders. Instead of looking at the bigger picture this approach is focused on local perceptions and identifying the strengths, possibilities, weaknesses, and threats. The role of the local government is to create context and to collecting stakeholders' ideas and initiatives.

National public authority
On the scale of a neighbourhood mobility hub, there are not directly involved. They support the other layers of government with policy goals, rules, and regulations on (sustainable) shared mobility, but often not specifically focus on mobility hubs.

Regional public authority
Regional stakeholders have an important role within the theme of mobility. Many of the current challenges within this field are on a regional scale. The province can take various roles regarding the governance of mobility hubs, as described in case of the province Gelderland. The precise role of the province is dependent on the type and scale of mobility hub, as well as the services and facilities. Provinces can: regulate, direct, stimulate, facilitate or laissez-faire (APPM & Goudappel, 2020):

- Regulate: legal and regulatory framework. The crucial basis for the regulatory framework is currently the 'Wet Ruimtelijke Ordening', soon to be succeeded by the Environment and Planning Act (*Dutch: Omgevingswet*). The province defines the policy goals regarding mobility and spatial development. The province either sets a framework for the developments for other parties or appoints itself as an important investor and decision maker of the process.
- Direct: through a directing role the province focuses on the development, tendering and monitoring of public transport and traffic in the region. They are the granter of public transport and are responsible for the construction and maintenance of provincial roads. Besides, they can also direct the spatial domain by, for example, appointing areas that need to be developed for housing with again influences the mobility.
- Stimulate: with a stimulating approach the province wants to achieve a certain policy goal but leaves the realisation and operation up to another party. The province can stimulate through providing subsidies, for example to shared mobility or hub providers.
- Facilitate: the province can have a facilitating or connecting role by sharing and bundling knowledge across several parties or providing subsidies.
- Laissez-faire: in a laissez-faire approach the province does not have any interest and leaves the process and initiative to others.

Local public authority
A municipality is closely involved with the implementation of mobility hubs. In general municipalities are setting their own ambitions related to creating a sustainable and liveable environment, although within the boundaries of the regional policies as set by the province. The municipality is responsible for the public space and with respect to mobility and the environment, the municipalities aim to create healthy and sustainable environment and

transportation. Shared mobility could be one of the strategies to achieve this. Besides, it is also the responsibility of a municipality to ensure that the mobility hub is benefiting all citizens and needs to monitor the (undesired) effects of the hubs. Therefore, municipalities should be consulted for identifying potential mobility hub locations and planning requirements associated with the implementation of a new mobility hub (SEStran, 2020).

Cohen & Shaheen (2018) have described several ways in which planners and local municipalities can support shared mobility. This list can be also applied to supporting mobility hubs providing shared mobility:

- Become partner of shared modes: municipalities can support shared mobility by assisting the shared mobility providers with marketing and administrative tasks. Joint marketing campaigns can ensure that programs are visible in several communication channels and the public space. Secondly, public agencies can become a business customer of the shared mobility services such as for example, replace their current vehicle fleet with vehicles of a carsharing provider. Although this is not directly linked to a mobility hub this can enlarge the visibility and thus the brand awareness of the carsharing provider which could promote the usage of carsharing. Thirdly, Cohen & Shaheen (2018) mention that public agencies can support shared mobility providers by offering administrative help, for example in the sense of office space for a reduced tariff.
- Allocating funds: grant and loans from municipalities are a way to support shared mobility and hub providers. These funds can be used to finance feasibility or pilot studies.
- Risk-sharing partnerships: a risk-sharing partnership is a strategy to reduce the financial risk for the shared mobility provider. This is an appealing strategy when launching the shared mobility services in a new location that may not necessarily be financially feasible for the shared mobility operator. The public agency will pay the costs for maintaining the service availability.
- Giving developer incentives for the inclusion of shared mobility: planning departments can implement policies to stimulate the inclusion of shared mobility by setting low parking standards and easing zoning regulations.
- Supplying access to public rights-of-way: access to public rights-of-way support shared mobility through giving the providers access to (designated) parking space and other infrastructures for their vehicles.
- Incorporating shared mobility intro plans and planning processes: with the incorporation of shared mobility into policies a longer-term vision for the role of shared mobility is established. Besides, it can help in the understanding of the current and future impact of shared mobility on the community.
- Addressing key public policy issues affecting shared mobility: finally, through public policy, authorities can help to ensure that shared mobility provides the perceived benefits. Municipalities can provide a supportive policy environment such as minimising regulation and avoiding policy ambiguities regarding shared mobility.

Shared mobility providers/hub providers

The shared mobility or hub providers are the providers of the hub in its entirety or providers of the available shared mobility services in the hub such as carsharing or bike sharing. These shared mobility providers are private companies, ranging from start-ups to large internationals, but are dependent on (regulations) of the local authorities. Shared mobility providers and the hub owners need to have the permission to use the public space and stall their vehicles and services. This can be either through using public infrastructure or through placement and use of specific stalling or parking infrastructure (van Gils, 2019a).

The shared mobility and hub providers are generally interested in a high usage of their services and customer satisfaction to get high revenues. Their challenge is to balance the demand and supply, as well as quality and price of shared vehicles in the hub. In the previous section (3.3.2), several hub providers are discussed, Table 28 shows an overview of the currently active mobility hub providers and their collaboration with shared mobility providers. Apart from the providers listed in this table that are currently operating through a mobility hub, there are many more shared mobility providers present in the Netherlands though (currently) not providing their services in a mobility hub format. Even when these provides are not offering their services at the mobility hub itself but nearby, they could still influence the mobility hub (usage) as more shared vehicles raises awareness and could stimulate other people to take up shared mobility.

Table 28: Current mobility hub and shared mobility providers in the Netherlands

Hub providers	Carsharing providers	Bike sharing providers	E-bike sharing providers	Cargo bike sharing providers	LEV sharing providers
eHUB	Amber Wedrivesolar Goodmoovs Share Now	-	Urbee Deelfiets Nederland Bondi	Cargoroo	Birò
Mobipunt	JustLease	Uwdeelfiets	-	-	-
Reis via hub Drenthe & Groningen	?	-	Deelfiets Nederland	-	-
Hely	Mywheels	Union	Urbee Gazelle	Cargoroo Urban Arrow	-
Juuve	Juuve/JustLease	-	Urbee	-	-
Amber	Amber	-	-	-	-
MOBIHUB	-	-	Deelfiets Nederland	-	-

Project developers

Project developers can be important actors within the implementation of mobility hubs when the hubs are placed in or near housing developments. As many cities are working on inner-city development projects, while the housing density and pressure of transport system is already high, the current mobility behaviour needs to change to accommodate for the new houses and residents. In the development projects it is a rising trend to provide alternatives for car traffic in the form of public transport and MaaS, in combination with a lower parking standard. Hubs play a role in this tendency as a 'docking station' for shared vehicles (Kwantes et al., 2019). The main interest of the developers is to make profit as a result of the sale of the developed real estate. On one side creating hubs could be beneficial for them because it decreased the need for parking spaces and frees up space for more houses or green space. On the other side, the developer is focused on the prospective residents that could desire sufficient parking places for their private vehicles and not necessarily want shared mobility alternatives.

Public transport provider

When the mobility hub is also connected to the public transport network, public transport providers are a stakeholder in the implementation and operation of the mobility hub. The public transport provider benefits from the expansion of his mobility services that complement public transport.

Community groups
In some cases, residents are represented by an owner cooperative *(Dutch: VvE)*. Cooperation with these not-for profit organisations such as the VvE and other community groups is then suggested to improve the mobility hub, to have it better suited to the residents wishes and thus increase the usage.

Technology providers
Many of the shared mobility providers operate through a technological platform (MaaS platform) that is often outsourced through another technology operator that manages the online booking and billing process and/or real-time tracking of the vehicles. They thus play an important role in the user demand and user acceptance of mobility hubs.

Assets, infrastructure, and utility companies
Some other stakeholders with relatively little power and interest that in specific cases could be included in a mobility hub are physical assets and infrastructure such as charging stations for electric vehicles, kiosks or parcel lockers. The suppliers of these services should be consulted in the planning phase of the hub and but have relatively little power and interest.

Other mobility hubs
As the number of established mobility hubs is growing, these mobility hubs can offer knowledge and expertise for mobility hubs to be. By getting insight in the lessons learnt and approach to challenges the new mobility hub can benefit by a high(er) user acceptance and usage. Moreover, a network of mobility hubs can support the individual usage of the hubs and coherence could increase the recognisable and familiarness.

Consultants
Consultants could advise municipalities or private parties on strategic or operational issues of mobility hubs. They therefore only have an indirect influence in the project.

D.2. Interaction of stakeholders
Figure 41 shows the actors as discussed in the previous subsection in boxes, their relations are depicted by the arrows. Double headed arrows mean that the relations work in both ways, both actors influence each other. Some arrows are dashed because they are not necessarily involved in mobility hubs on a neighbourhood level but could still influence other actors indirectly.

Depending on the scale of the mobility hub, the national and regional government can be of influence. They affect the municipality mainly through policies. The regional government, the provinces, can interact with the municipalities through different roles, such as: regulate, direct, stimulate, facilitate. Besides, they are also responsible for the regional public transport network. As described above, municipalities can take various roles but are a crucial actor within the implementation of a neighbourhood mobility hub. They have to collaborate with the community, mobility hub provider and if applicable a project developer (especially when the mobility hub is placed in a development area). A mobility hub provider can organise the entire hub operation itself, but often works together with shared mobility and technology providers for the provision of the vehicles and technical support. When there is also a public transport connection at the mobility hub, the hub provider has to collaborate with the public transport provider. This entire process of stakeholder and collaboration is depicted in Figure 41.

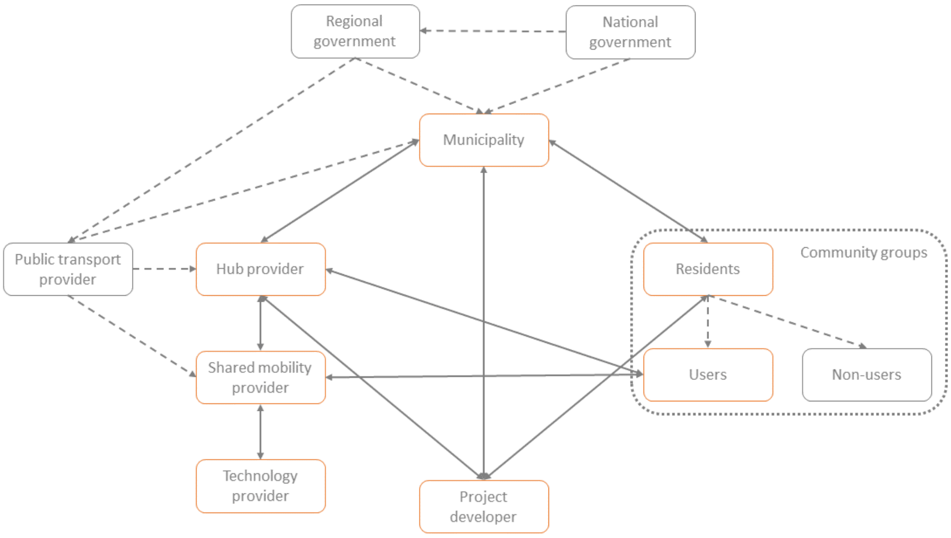


Figure 41: Stakeholder interaction

D.3. Power-interest grid

Based on the stakeholder identification in the previous section, a power-interest grid is comped that visualises the stakeholders' interest and power. The horizontal axis displays the power of the stakeholders and the vertical axis represent the interest of an actor. The stakeholders are categorised in four groups: subjects, players, crowd, and context setters. Players have interest and power, subjects have interest but no or little power, context setters have less interest, but they do have power and the crowd has both little interest and little power.

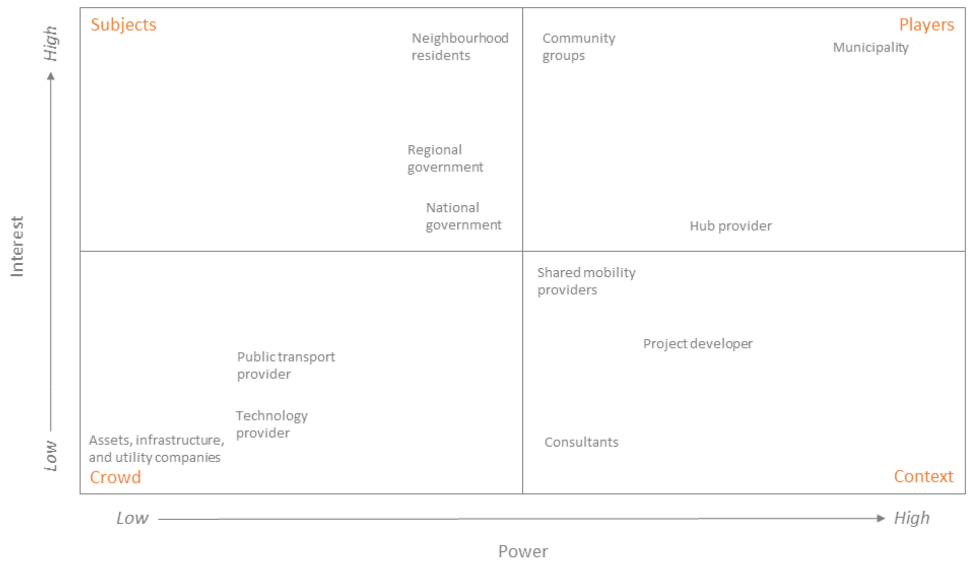


Figure 42: Power-interest grid

E. Policy goals analysis

Table 29: Identified policy goals for shared mobility

Mode/measure	Policy goals	City	Documents
Shared mobility	Free up public space	Almere	Mobiliteitsvisie 2020-2030 Almere
Car sharing	Reduction VKT	Amsterdam	Agenda Autodelen
Car sharing	Reduction car usage	Amsterdam	Agenda Autodelen
Car sharing	Improvement air quality	Amsterdam	Agenda Autodelen
Car sharing	Reduce pressure on public space	Amsterdam	Agenda Autodelen
Car sharing	Reduction car ownership	Amsterdam	Agenda Autodelen
Shared mobility	Improvement mobility options and accesibility	Amsterdam	Deelmobiliteit, kansen voor de stad
Shared mobility	Alternative for car trips	Amsterdam	Deelmobiliteit, kansen voor de stad
Shared mobility	Reduced parking pressure	Amsterdam	Deelmobiliteit, kansen voor de stad
Shared micro-mobility	Stimulate healthy pleasure way of life	Breda	Gemeente Breda deelmobiliteit
Shared mobility	Free up public space	Breda	Gemeente Breda deelmobiliteit
Shared mobility	Attracting younger people	Breda	Gemeente Breda deelmobiliteit
Shared mobility	Accelerate the realisation of climate goals	Breda	Gemeente Breda deelmobiliteit
Shared mobility	Ensure accessibility of PT	Breda	Mobiliteitsvisie Breda
Shared mobility	More efficient use of public space	Breda	Mobiliteitsvisie Breda
Shared mobility	meer flexible mobility needs	Breda	Mobiliteitsvisie Breda
Car & bike sharing	Good addition to mobility system	Delft	Mobiliteitsprogramma Delft 2040
Car & bike sharing	Possibilities to make mobility more sustainable	Delft	Mobiliteitsprogramma Delft 2040
Shared mobility	Flexible alternative for (private) car	Delft	Mobiliteitsprogramma Delft 2040
Shared mobility	Guaranteeing accessibility	Delft	Mobiliteitsprogramma Delft 2040
Shared mobility	Reduce pressure on public space	Delft	Mobiliteitsprogramma Delft 2040
Shared mobility	Contribution to liveability in spatial developments	Delft	Mobiliteitsprogramma Delft 2040
Shared mobility	Reduction car usage and ownership	Delft	Mobiliteitsprogramma Delft 2040
Shared mobility	Improve last- and first mile of public transport	Delft	Kaders regulering deelvervoer op twee wielen Delft
Shared mobility	More efficient and less use of cars	Eindhoven	Agenda Deelmobiliteit Eindhoven
Shared mobility	Better use of public space and reduced pressure on infrastructure	Eindhoven	Agenda Deelmobiliteit Eindhoven
Shared mobility	Reduced CO2 emissions	Eindhoven	Agenda Deelmobiliteit Eindhoven
Shared mobility	Reduced parking space required	Eindhoven	Agenda Deelmobiliteit Eindhoven
Shared mobility	Contributes to transition from ownership to usage	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)
Shared mobility	Increasing mobility options	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)
Shared mobility	Transition to transport that takes up less space	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)

Mode/measure	Policy goals	City	Documents
Car sharing	Reduced car usage	Haarlem	Startnotitie beleid autodelen Haarlem
Car sharing	Reduced car ownership	Haarlem	Startnotitie beleid autodelen Haarlem
Car sharing	Free up public space	Haarlem	Startnotitie beleid autodelen Haarlem
Car sharing	Quality improvement of public space	Haarlem	Startnotitie beleid autodelen Haarlem
Car sharing	Better accesibility	Haarlem	Startnotitie beleid autodelen Haarlem
Car sharing	Tailor-made solutions for the accessibility and liveability of the rural area	Hollands Kroon	Mobipunten in de Kop van Noord-Holland
Shared mobility	More efficient use of public space	Nijmegen	Ambitiedocument Mobiliteit Nijmegen
Shared mobility	Increasing mobility options	Nijmegen	Ambitiedocument Mobiliteit Nijmegen
Shared micro-mobility	reduction car usage	Rotterdam	Fietskoers 2025 Gemeente Rotterdam
Shared mobility	More efficient use of public space	Rotterdam	Fietskoers 2025 Gemeente Rotterdam
Shared mobility	the mobility transition must be scaled and become visible and accessible to everyone	Rotterdam	Rotterdams klimaatakkoord mobiliteit
Shared mobility	Enrichment of mobility choices	Rotterdam	Rotterdamse mobiliteitsaanpak
Shared mobility	Reduce pressure on public space	Schiedam	Mobiliteitsvisie Gemeente Schiedam
Shared mobility	Solution for multimodal trips via PT nodes	Schiedam	Mobiliteitsvisie Gemeente Schiedam
Shared mobility	Reduce parking standards	Schiedam	Mobiliteitsvisie Gemeente Schiedam
Shared mobility	Getting people familiar with electric driving	Schiedam	Mobiliteitsvisie Gemeente Schiedam
Car sharing	More efficient use of public space	Utrecht	Mobiliteitsplan Utrecht 2025: Slimme routes, slim regelen, slim bestemmen
Car sharing	Purposeful mobility behaviour	Utrecht	Mobiliteitsplan Utrecht 2025: Slimme routes, slim regelen, slim bestemmen
Car sharing	Accessible, sustainable, safe and attractive public space	Utrecht	Mobiliteitsplan Utrecht 2025: Slimme routes, slim regelen, slim bestemmen
Shared mobility	More efficient use of public space	Utrecht	Mobiliteitsplan 2040 (Inspraakversie)
Shared mobility	Keeping city attractive	Utrecht	Mobiliteitsplan 2040 (Inspraakversie)
Shared mobility	Keeping city accessible	Utrecht	Mobiliteitsplan 2040 (Inspraakversie)
Shared mobility	Healthy mobility	Utrecht	Mobiliteitsplan 2040 (Inspraakversie)
Shared mobility	Accomodating growth in mobility	Utrecht	Mobiliteitsplan 2040 (Inspraakversie)

Table 30: Identified policy goals for mobility hubs

Policy goals	City	Documents
Accessible, clean and liveable city	Amsterdam	Programma Smart mobility 2019-2025
More efficient use of public space	Amsterdam	Programma Smart mobility 2019-2025
Creating transfer points from private modes to shared modes	Amsterdam	Programma Smart mobility 2019-2025
Reduce car ownership	Amsterdam	Programma Smart mobility 2019-2025
Hubs and shared mobility reinforce each other	Breda	Gemeente Breda deelmobiliteit
Important role in the transition from mobility to multi-modal mobility	Breda	Mobiliteitsvisie Breda

Policy goals	City	Documents
Limiting the required number of parking places	Breda	Mobiliteitsvisie Breda
Contribute to a car-free city centre	Breda	Mobiliteitsvisie Breda
More efficient use of cars	Delft	mobiliteitstranisitie Delft
Enabling mobility transition	Delft	mobiliteitstranisitie Delft
Efficient, clean, tailored and connected mobility	Den Haag	Smart mobility visie Den Haag
Enabling the use of different transpot modes	Den Haag	Smart mobility visie Den Haag 2
Facilitate transfer options	Eindhoven	Agenda Deelmobiliteit Eindhoven
Stimulating multi-modal trips	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)
Preventing take car use for the entire journey for granted	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)
Offering mobility for everyone	Groningen	Groningen Goed op Weg (concept mobiliteitsvisie)
Improve accessibilty in a broad sense (independence car, public transport,..)	Hollands Kroon	Mobipunten in de Kop van Noord-Holland
Providing the opportunity for users to make a conscious mode choice each trip	Nijmegen	Ambitiedocument Mobiliteit Nijmegen
Stimulating multi-modal trips	Utrecht	Mobiliteitsplan 2040 (Inspraakversie)

Table 31: Shared mobility policy goals categorised. Statements including sources are represented in Table 29 (Appendix E). Number between brackets is number of times this statement is reported in the documents. (Note: Original text in Dutch, translated to English)

Public space	Sustainability, emissions, climate, air quality, liveability	Car usage and ownership	Accessibility	Other
More efficient use of public space (7)	Improvement air quality	Reduced car usage (5)	Increasing mobility options (5)	Attracting younger people
Reduce pressure on public space (4)	Contribution to liveability in spatial developments	Reduced car ownership (3)	Guaranteeing accessibility (4)	Getting people familiar with electric driving
Free up public space (3)	Possibilities to make mobility more sustainable	More efficient use of cars	Improve last- and first-mile of public transport (2)	Alternative for car trips
Reduced parking space required (2)	Keeping city attractive	Reduction VKT	Ensure accessibility of PT	
Accessible, sustainable, safe, and attractive public space	Reduced CO2 emissions	Flexible alternative for (private) car	Accommodating growth in mobility	
Better use of public space and reduced pressure on infrastructure	Accelerate the realisation of climate goals	Contribute to transition from ownership to usage	Accessible, sustainable, safe, and attractive public space	
Quality improvement of public space	Healthy mobility		Good addition to mobility system	
	Purposeful mobility behaviour		Tailor-made solutions for the accessibility and liveability of the rural area	
	Stimulate healthy pleasure way of life			
	Accessible, sustainable, safe, and attractive public space			

Table 32: Mobility hub policy goals categorised. Statements including sources are represented in Table 30 Appendix E. Number between brackets is number of times this statement is reported in the documents. (Note: Original text in Dutch, translated to English)

Public space	Sustainability, emissions, climate, air quality, liveability	Car usage and ownership	Accessibility	Multimodality	Other
More efficient use of public space	Accessible, clean, and liveable city	Reduce car ownership	Improve accessibility in a broad sense (independence car, public transport,..)	Stimulating multi-modal trips (2)	Contribute to a car-free city centre
Limiting the required number of parking places	Efficient, clean, tailored, and connected mobility	More efficient use of cars		Enabling the use of different transport modes	Hubs and shared mobility reinforce each other
Efficient, clean, tailored and connected mobility	Providing the opportunity for users to make a conscious mode choice each trip	Preventing taking car use for the entire journey for granted	Offering mobility for everyone	Important role in the transition from mobility to multi-modal mobility	Enabling mobility transition
				Facilitate transfer options	
				Creating transfer points from private modes to shared modes	
				Providing the opportunity for users to make a conscious mode choice each trip	
				Efficient, clean, tailored, and connected mobility	

F. Interview guide expert interviews

Introduction (based on (Wilson, 2014)) **± 10 min**

- Brief participant
- Introduction myself
- Introduction of research, scope and methodology
- Explain goals of interview
- Review interview method, use of data recording

Participant introduction **± 2 min**

EN

- What is your role and background in your organisation?
- How are you involved with shared mobility and/or mobility hubs?

NL

- Wat is je rol en achtergrond binnen de organisatie waar je werkt?
- In hoeverre en op welke manier ben je betrokken bij deelmobiliteit en mobiliteitshubs?

Without showing model: questions on most important goals, factors and relations ± 10 min

EN

- What do you believe are the benefits of a neighbourhood mobility hub? What are the main benefits and what are the co-benefits?
- What do you believe should be the main reasons for implementing a neighbourhood mobility hub?
- Based on what would you say 'this mobility hub is a success'?

NL

- Wat zie jij als voordelen van een mobiliteitshub? En wat zijn dan de meest belangrijke en de iets minder belangrijke voordelen?
- Wat denk jij dat de belangrijkste redenen zijn voor het implementeren van een mobiliteitshub?
- Op basis waarvan zou je zeggen dat een mobiliteitshub een succes is?

Introduction CLD ± 5 min

- Explain why chosen for this method
- Explain how to use and read diagram
- Explain how arrived at model

Show and review model: effects and factors **± 15 min**

Start left upper corner: 'mobility hub usage'

EN

- Which attributes/contextual factors are, in your opinion, essential for a neighbourhood mobility hub? (arriving arrows)
- What do you think are the dominant motives for using a mobility hub? (arriving arrows)

NL

- Welke attributen/contextuele factoren zijn volgens jou essentieel voor een mobiliteitshubs?
- Wat denk jij dat de meest dominante redenen zijn voor het gebruik van een mobiliteitshub?

Walk through model

EN

- Do you agree with the direct effects of 'mobility hub usage'? (departing arrows)
- Do you agree with the influencing factors for 'private car usage'? (arriving arrows)

NL

- Ben je het eens met de directe effecten van 'mobility hub usage'?
- Ben je het eens met de beinvloedende factoren voor 'private car usage'?

Repeat for other variables. Depending on identified main goals, discuss whether the depicted causal relations are correct.

Final closing questions **±15 min**

EN

- Based on the model (and if appropriate any additions done), which factors and relations do you perceive to be the most important? And is it possible to identify critical/essential factors and relations?
- Do you feel like there is still something missing in the model?
- Is there any part of the model that you would like to further discuss or feel like we have not covered properly?
- Do you have any general remarks with respect to the visualisation of the diagram?

NL

- Kijkend naar het model (en eventuele toevoeging), welke factoren en relaties zou je identificeren als meest belangrijk? En is het mogelijk om kritieke/essentiële factoren en relaties aan te wijzen?
- Ontbreekt er volgens jou nog iets aan het model?
- Is er nog iets uit het model dat je uitgebreider zou willen bespreken?
- Heb je nog algemene opmerkingen over de weergave van het model?

G. Interview guide ex-post mobility hub evaluation interviews

Introduction (based on (Wilson, 2014))

- Brief participant
- Introduction myself
- Introduction of research, scope and methodology
- Explain goals of interview
- Review interview method, use of data recording

Participant introduction

- Wat is je rol en achtergrond binnen de organisatie waar je werkt?
- In hoeverre en op welke manier ben je betrokken bij mobiliteitshubs?

Questions regarding hub(s)/shared vehicles, implementation, and expectations

Municipalities

- Kunt u wat vertellen over de visie van x op deelmobiliteit in het algemeen?
- Kunt u wat vertellen over de hubs in x en hoe ze tot stand zijn gekomen?
  - Sinds wanneer?
  - Modaliteiten aanwezig
  - Locaties
  - Initiatief

Shared mobility providers

- Kunt u wat vertellen over de visie van x in het algemeen?
- Kunt u wat vertellen over de hubs/deelmobiliteit (in steden x) en hoe ze tot stand zijn gekomen?
  - Sinds wanneer?
  - Modaliteiten aanwezig
  - Locaties
  - Initiatief

- Wat zien jullie als grootste voordelen van mobiliteitshubs? (t.o.v. free-floating?)

Municipalities

- Wat waren van tevoren de verwachte kosten en baten?

Shared mobility providers

- Hoe kijken jullie aan tegen multimodale hubs?

Questions on effects and usage of hub(s)/shared vehicles

- Kunt u wat vertellen over het gebruik van de hubs?
  - Frequentie
  - Gebruikers
- Andere opvallende dingen
- Is er wat te zeggen over de effecten van een hub?
  - Autogebruik
  - Autobezit
  - Leefbaarheid
  - Bereikbaarheid
- Of eventuele andere (beleids)doelen
- Is het mogelijk om aan het wijzen welke factoren invloed hebben op het gebruik en effect van een hub
- Zijn er bepaalde typen locaties/hubs waar jullie meer of minder potentie in zien of is er weinig verschil in?
- Hoe zouden het gebruik en de effecten van de hub (in de toekomst) nog groter kunnen worden

Questions on collaboration between stakeholders, municipality/providers

<u>Municipalities</u>

- Hoe zien jullie de relatie tussen overheid en marktpartijen bij hubs?
  - Is hierin verschil zichtbaar tussen verschillende steden/aanpakken
  - Zo ja, wat zijn dan de voor- en nadelen?
- Wat voor soort rol nemen jullie op?
- Welke taken horen bij een gemeente en wat is voor de aanbieders?

<u>Shared mobility providers</u>

- Hoe kijken jullie aan tegen eventuele eisen die gemeentes stellen aan deelmobiliteit/hubs?