From Policy to Practice: Evaluating Mobility Hubs

Developing an ex-post evaluation method to assess the performance of urban mobility hubs in regard to their policy objectives

Master Thesis
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From Policy to Practice: Evaluating Mobility Hubs

Master Thesis Report

by

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Preface

With the completion of this thesis, my academic career at the TU Delft comes to an end after years of learning. This journey started with the bachelor's degree in Systems Engineering, Policy Analysis and Management, where I learned to analyse socio-technical systems. During my bachelor, my interest developed in exploring the accessibility and transportation domain. Afterwards, I started my master's in Construction Management Engineering which provided me with more perspectives and insights into the management sector of large-scale projects. Within my master's degree, my interest in area development became more evident. Here, I learned that mobility is a crucial component of resilient urban development and this was something that inspired me to conduct this research. These interests formed the starting point of the research which I have conducted on mobility hubs, a mobility intervention which is used in area development. After exploration in this field, it became evident that knowledge was still missing on how to evaluate these interventions.

This thesis would not have been possible without the guidance and support of various people. Therefore, I would like to thank the supervision from both my TU Delft and APPM Management Consultants supervisors. Without their insights, feedback and guidance throughout the research, this would not have been possible. First, I would like to thank Erik-Jan for our inspiring meetings, where we could discuss different aspects of my research. Your critical reflection made sure that I would think beyond what is evident and explore further deepening of concepts. Marian, thank you for your valuable feedback which made sure that the research reached a higher academic level, especially due to your knowledge in research methods. Also, your reflection made sure that findings were appropriately formulated. Jan Anne, I would like to thank you for your knowledge in the mobility field, especially in performing case studies. Here, you helped me out with my methodology and your enthusiasm was highly appreciated.

Further, a special thank you goes to Bernice, my supervisor from APPM. We have had many meetings where you guided me along the way in this research. Your expertise in the field and your encouragement really helped me out during this period. Not only did you help me out with theoretical input, you also really supported me during this process which is very valuable. Also, thank you Bas, you provided me with very useful contacts for conducting my interviews. Without this information, my process would not have been as smooth. Furthermore, a warm thank you to all the colleagues at APPM which showed genuine interest in my research and provided me with motivation to continue. It was a pleasure to work with you all. I would also like to express my gratefulness to all the interview participants, without your insights, this research would not have been possible. It was very enjoyable to see how passionate the participants were about sharing their knowledge in the mobility hub field.

Finally, I am also very grateful for the support and encouragement of my family, friends and house mates. You have made sure that I always felt eager to thrive for the best, while also providing me with a way to express my doubts and insecurities. Overall, I hope that this thesis provides some new insights into mobility hubs and stimulates responsible stakeholders to explore ways for evaluating by providing possible guidelines. I wish you a pleasant read and I hope that this thesis will give you some new insights.

Lisa Rijnbeek
Delft, February 2026

Summary

Mobility hubs have emerged as policy-driven strategic tools within sustainable mobility strategies in the Netherlands. In response to increasing urban density, climate-related challenges, limited public space and the continued dominance of private car ownership, mobility hubs are used to address such societal challenges. Municipalities are increasingly implementing mobility hubs as multifunctional interventions. These hubs are intended to function as a transportation infrastructure, where a convenient transfer point is offered for various transportation modes such as public transportation and active mobility to shared mobility. Besides from this function, it is aimed to contribute to broader policy ambitions including accessibility, sustainability, liveability and spatial quality. In general, the development of mobility hubs is considered as more space-efficient and sustainable mobility options. Despite their rapid integration in policy documents and implementations, systematic evaluation of whether mobility hubs actually contribute to these intended policy objectives remains limited. Evaluation often focuses on usage statistics rather than societal impact.

This research addresses this gap by exploring how the effectiveness of mobility hubs can be assessed. Consequently, the research bridges theoretical ambitions to policy practice by developing and testing an ex-post evaluation framework for realised mobility hubs. Within this assessment, a specific focus is created on their effectiveness in relation to predefined policy goals. The study focuses on mobility hubs in the Netherlands and applies the developed framework to one specific urban case in Amsterdam in order to test its applicability in practice. To guide this research, the following main research is addressed:

> **MRQ:"How can the effectiveness of realised urban mobility hubs be assessed through an ex-post evaluation framework, in relation to their intended policy goals?"**

To answer this question, four sub-questions were formulated. These sub-questions explore the policy goals and objectives underlying mobility hub development across Dutch municipalities (RQ1), current municipal practices for monitoring and evaluating realised mobility hubs (RQ2), suitable indicators to assess the desired effects of urban mobility hubs (RQ3) and the applicability of a developed evaluation framework through a case application of one urban mobility hub in Amsterdam (RQ4).

For conducting this research, a mixed-method approach was used, combining a literature review, policy analysis, semi-structured expert interviews and a case application. By combining theoretical insights with empirical evidence, the research aims to bridge the gap between ambitious policy objectives for mobility hubs and the limited understanding of their actual performance after implementation. This research conceptualises mobility hubs not merely as a transport infrastructure, but as developments aimed at creating societal impact in challenges such as public space scarcity and climate-change. Building on literature on sustainable mobility and urban liveability, mobility hubs are understood as strategic instruments that can potentially influence sustainable mobility behaviour, spatial quality and social inclusion.

The literature review demonstrates that while there is broad consensus on the mobility function of hubs facilitating multimodal travel, definitions vary when it comes to their additional roles and environmental contexts. Mobility hubs are explained to have a complex context-dependent nature, where aspects such as urban context and location influence functioning and purposes. The analysis of existing typologies shows that mobility hubs vary significantly in scale, function and context, ranging from small neighbourhood hubs to large corridor nodes. This variation reinforces the importance of context-sensitivity when assessing hub performance. Furthermore, the review highlights a key gap in existing research: evaluation efforts have largely focused on implementation processes and usage statistics, while ex-post assessments of societal impact and policy effectiveness remain scarce.

The policy analysis in this research examined policy documents from the municipality of Amsterdam and the province of Noord-Holland, providing a specific zoom-in on an urban context. By doing so, dif-

ferent objectives and goals were explored that form the development of the mobility hub. The analysis of policy documents reveals that mobility hubs are consistently associated with broad and ambitious policy goals, including improving accessibility, stimulating modal shift away from private car use, reducing parking pressure and enhancing public space. However, the translation of these overarching ambitions into concrete, measurable objectives is limited in existing strategies and documents. The policy analysis explored multiple mentioned objectives and categorised these in impact themes, where each theme addresses a different societal challenge. These themes are sustainable accessibility, spatial quality and inclusive cohesion. Although general ambitions are widely shared, their interpretation and prioritisation differ between municipalities. This confirms that mobility hubs cannot be evaluated using a fixed assessment. Instead, evaluation must take into account the specific spatial, functional and policy context in which a hub is developed.

Furthermore, expert interviews with municipal and provincial representatives as well as with developers provided insight into current evaluation practices, challenges and expectations. The interview findings show that systematic evaluation of realised mobility hubs is still limited. While municipalities do collect certain forms of monitoring data such as usage statistics of shared mobility, these data are rarely used to assess broader societal or spatial impacts. Evaluation practices are often fragmented and constrained by limited data availability and uncertainty regarding causality. As a result, there is a strong reliance on assumptions rather than evidence when assessing hub effectiveness.

A central contribution of this research is the development of a generic ex-post evaluation framework that translates abstract policy ambitions into measurable indicators. Effectiveness is distinguished in this research for two perspectives: the usage perspective and the policy perspective. The research shows that effectiveness should not only be understood in terms of usage levels, but also in terms of contribution to policy goals. Therefore, the evaluation framework considers indicators to measure societal effects from a policy perspective. Indicators were operationalised based on policy documents and interview findings, where the interview findings were mostly attributable for defining the indicators. This development demonstrates that it is to some extent possible to systematically connect policy objectives to observable effects.

At the same time, the research highlights that evaluation requires careful interpretation. Indicators differ in scale, some are measured directly at the hub level, such as the reduction of nuisance caused by shared vehicles or improvements in the reallocation of public space. These can be more directly related to the presence of the hub. Other indicators, such as modal shift or changes in car ownership, are measured at a broader city or regional level and are influenced by potential external factors. In such cases, it is difficult to attribute observed changes solely to the development of a single hub. The framework therefore does not provide definitive causal conclusions but supports structured reflection on possible contributions, where additional research is needed to explore these relations further.

The case application in Amsterdam demonstrates that the framework is both applicable and adaptable. When applying the framework to the Appeltjesmarkt hub, several adjustments were necessary. Certain indicators proved less relevant in the dense city centre context, where car use is already restricted and parking pressure is high. Other indicators, particularly those related to spatial quality and nuisance reduction, were especially relevant given Amsterdam's policy focus on efficient use of public space. The case application reinforces the importance of contextual interpretation. In addition, the application also revealed practical considerations, such as the need for collaboration with shared mobility providers to obtain data. It is argued that data availability and accessibility is of high importance for the functioning of the framework, due to its quantitative nature. Moreover, the case showed that quantitative indicators alone do not fully capture user motivations or behavioural changes, suggesting that additional qualitative insights could strengthen the evaluation in future research. The final proposed adaptive evaluation framework is illustrated in Figure 1, where all these different considerations are incorporated.
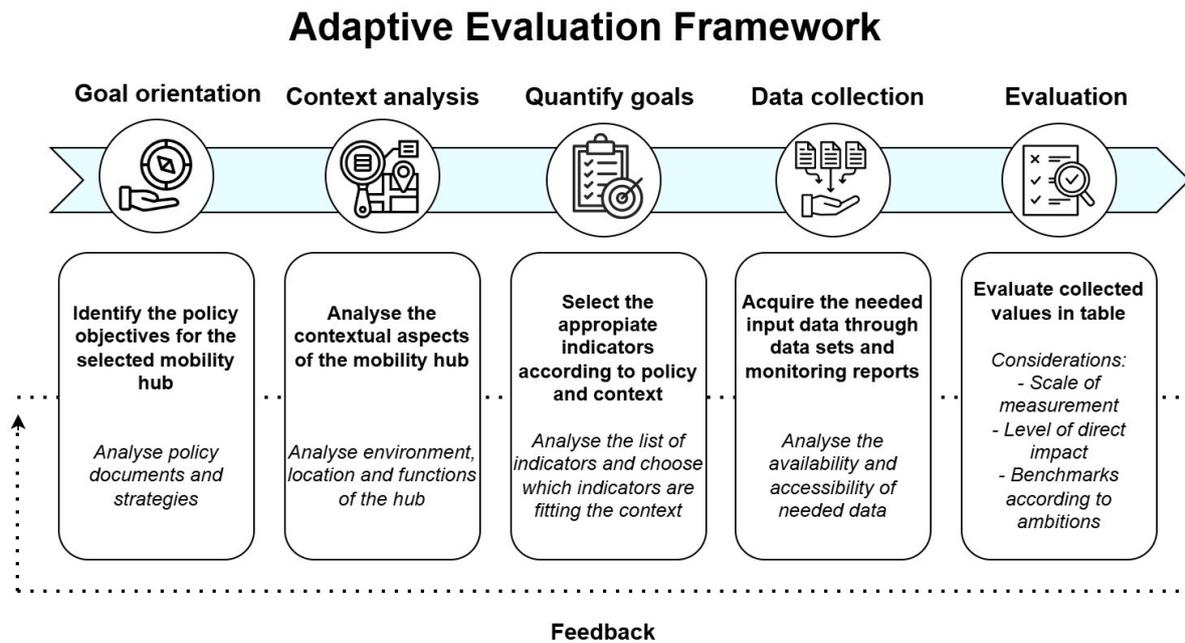
Adaptive Evaluation Framework

Goal orientation	Context analysis	Quantify goals	Data collection	Evaluation

Identify the policy objectives for the selected mobility hub	Analyse the contextual aspects of the mobility hub	Select the appropiate indicators according to policy and context	Acquire the needed input data through data sets and monitoring reports	Evaluate collected values in table
Analyse policy documents and strategies	*Analyse environment, location and functions of the hub*	*Analyse the list of indicators and choose which indicators are fitting the context*	*Analyse the availability and accessibility of needed data*	*Considerations: - Scale of measurement - Level of direct impact - Benchmarks according to ambitions*

Feedback

Figure 1: Adaptive evaluation framework

This research contributes to both academic literature and policy practice in several ways. From an academic perspective, it addresses the lack of ex-post evaluation frameworks for mobility hubs by proposing a structured, impact-oriented approach that acknowledges complexity and context-dependency. The research expresses the understanding of mobility hubs as strategic interventions rather than isolated transport infrastructures. From a policy perspective, the findings underline the need for more grounded expectations regarding what mobility hubs can achieve in developments. The evaluation framework offers municipalities a practical tool to reflect on hub performance, support learning across projects and improve alignment between policy goals and realised outcomes. By developing and testing an ex-post evaluation framework, the research provides a first foundation for more evidence-informed decision-making in mobility hub development. While mobility hubs hold significant potential as instruments for sustainable urban mobility, their contribution to societal challenges can further be explored. This research proposes a quantitative assessment method for ex-post evaluation which acknowledges context-dependency and suggests further research on underlying motivations and drivers for the use of mobility hubs.

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Introduction

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1.1. Research background

Urban area development is evolving rapidly due to factors such as population growth. This development creates new opportunities for mobility. Rapidly growing needs for efficient urbanization arise from the pressure to create liveability while facing a lack of space. As populations continue to grow, current mobility systems often do not meet the need for creating social and environmental sustainability (Papadakis, Savvides, Michael, & Michopoulos, 2024). Here, competing needs are creating more accessibility while aligning with sustainability goals since more mobility generally leads to more emissions. Mobility and transportation are key components in the energy transition, with the transportation sector being one of the largest polluters in the European Union, accounting for approximately one third of the total greenhouse gas emissions in 2023 (Dolge, Barisa, Kirsanovs, & Blumberga, 2023). Due to climate change and the necessity to reduce the carbon footprint, sustainable mobility is more important than ever before. Therefore, new mobility developments need to explicitly consider sustainability improvements. Urban development seeks mobility opportunities that both enhance accessibility and liveability while addressing a lack of space and sustainability goals (Loorbach et al., 2021).

However, the research by Papadakis et al. (2024) states that even though cleaner transportation methods are available, the extensive use of private vehicles still offers greater advantages for users. This results in a relatively slow adoption of more sustainable mobility methods such as shared mobility, which often does not offer certain comfort advantages as with private cars. As for now, the Netherlands is mostly centred around private car ownership as the primary transportation method. Consequently, the Netherlands had a car ownership of 9,42 million vehicles at the start of 2025 of which 74,2% percent are fuelled by gasoline (Centraal Bureau voor de Statistiek, n.d.). The Netherlands aims to increase the share of electric cars by setting various sustainability guidelines, but a high percentage of private cars remains fuelled by gasoline. Not only does using a private gasoline fuelled car create pollution, usage of private cars also creates a lack of space. For example, approximately 13% of Amsterdam's city surface was used as a parking space and parked and driving cars occupied approximately 50% of all street space in 2022 (Rebel-Group, 2023). Thus, it can be stated that private car ownership, besides its convenient usage, remains a key player in pollution and creates less public space. This results in the need for a modal shift towards more sustainable and less space-demanding transportation methods.

In an attempt to address this need, a mobility concept which is called mobility hubs has emerged. These mobility hubs can be defined as physical areas that offer a convenient transfer between different available transportation modalities, including shared transportation and possibly public or private transportation options (Blad, De Almeida Correia, Van Nes, & Annema, 2022). There are many different types of mobility hubs which can be distinguished, all serving different purposes to their environment and social context. Research by Weustenenk and Mingardo (2022) distinguishes six different types of mobility hubs, from small-scale community hubs to large-scale city centre hubs. Additionally, different typologies of mobility hubs are presented, in which mobility hubs are distinguished into different conceptual names. For example, the research of Roukouni, Junyent, Casanovas, and De Almeida Correia

(2023) explains that the typology of hubs can be based on various factors such as size, function and spatial scale.

The mobility hub concept originates from previous initiatives aimed at creating junctions in transportation such as Park-and-Ride (P+R). Offering such physical connection points for different transportation types creates a larger offer of transportation modes for travellers, as hubs can function as physical links for the start, end and transfer point of a trip (Ministerie van Infrastructuur en Waterstaat, 2025). Mobility hubs are closely related to the concept Mobility as a Service (MaaS), which integrates different forms of transportation and their services into an on-demand mobility platform (Caiati, Rasouli, & López, 2025). This highlights the shift towards better integration of multimodal transportation methods, as well as the shift towards creating more sustainable travel chains.

The potential of mobility hubs thus rises from sustainable and accessible policy aims, creating a new opportunity to tackle pressing societal challenges. Arnold, Frost, Timmis, Dale, and Ison (2022) describe the aim of mobility hubs as follows: "Mobility hubs (MHs) have been identified as a mechanism to aid the move toward a sustainable transport network and are at various stages of implementation in cities throughout the world". Another example of the expectations of mobility hubs is the following: "Mobility hubs promise to be visible, accessible, and integration-enabling spaces, where public transit, shared mobility, micromobility and active travel modes co-exist harmoniously alongside infrastructure facilities like charging and sharing stations." (Nikitas, Alyavina, Sadik, & Michalakopoulou, 2025). However, the research by Nikitas et al. (2025) expresses that there are still uncertainties regarding the functionality of mobility hubs and their fit within urban development. In addition, the report of Rongen, Tillema, Arts, Alonso-González, and Witte (2022) expresses hesitation in the use of mobility hubs due to the limited use of multimodality within the Netherlands. Their report highlights the limited success of previous concepts such as P+R's, which resulted in insufficient modal shifts towards multi modal transportation. In this light, mobility hubs are a rather new concept and have not yet been operational for a long period, resulting in limited academic research on the potential of mobility hubs (van der Meer, Leferink, Geržinič, Annema, & Oort, 2023).

Nevertheless, the emergence of mobility hubs is evident in the initiatives taken by municipalities to expand the number of hubs within their region. One example is the Amsterdam Hubvisie (Hub Vision), where the municipality is using hubs as a strategy to become more liveable and accessible (Gemeente Amsterdam, 2021). Here, the city uses mobility hubs as an instrument to achieve different policy goals, under the assumption that the mobility hub will serve as a key component in reaching their objectives. Similarly, the municipality of Eindhoven has created a Masterplan Mobiliteit (Master Plan Mobility) 2025, aiming to ensure that mobility hubs are located within a distance no more than 200 to 300 metres throughout the city (Gemeente Eindhoven, 2025).

However, to what extent these mobility hubs actually contribute to the set goals such as creating a modal shift and creating more public space remains unclear, largely due to scarce data availability. Uncertainties are presented within literature on the effects of mobility hubs on mobility behaviour, while policymakers tend to have high expectations (van Nifterik, Marchau, Lenferink, Jittrapirom, & University, 2022). Furthermore, the report of Prskalo, Slavulj, Vidan, and Pavlek (2025) states that evaluations on the effect of mobility hubs are crucial for understanding their impact on travel patterns and environmental results. Despite that there is not much evaluation on the effects of mobility hubs, its potential remains high due to high policy interest. Therefore, this research will focus on the evaluation of mobility hubs within the Netherlands, with a focus on urban areas. Here, the performance of mobility hubs after implementation is explored in regard to the preset policy objectives. This research aims to contribute to evaluating to what extent mobility hubs are effective implementations to reach municipal policy goals.

1.2. Problem analysis

As has been introduced, mobility hubs aim to create a more sustainable and accessible transportation network within area development. Mobility hubs are used as building blocks for creating a new mobility opportunity to tackle pressing issues, such as mitigating climate change and a lack of public space. Furthermore, mobility hubs are increasingly implemented in Dutch transportation policies as a solution for creating accessibility within mobility development, in terms of dealing with population growth and meeting sustainability goals (Weustenenk & Mingardo, 2022). Strategic visions and policy goals of

municipalities within the Netherlands express the view that mobility hubs would serve as an overall remedy for tackling transportation-related issues such as limited urban space and poor liveability (Rongen et al., 2022). However, this perception might lead to a tendency to use mobility hubs to achieve broad policy goals, regardless of considering the actual realised effects of mobility hubs in different contexts. Developing mobility hubs has a high potential according to policy documents, yet they are still in development and can also be interpreted in different ways (Kennisinstituut voor Mobiliteitsbeleid, 2021)).

An example of a municipal strategy, that has been mentioned in the research background, is the Hubvisie 2021 from the municipality of Amsterdam which describes how different mobility hubs can be distinguished in goals and function within the city (Gemeente Amsterdam, 2021). Hubvisie 2021 is an elaborate municipal vision which shows the different types of mobility hubs implemented within the city and the corresponding goals. Furthermore, it can be explored which specific effects these policy goals aim for and thus what is explicitly desired by developing mobility hubs. In this regard, it can be assessed how mobility hubs perform in relation to the set out objectives and goals, as an integral understanding of what the impact of implemented mobility hubs is (Arnold, Dale, Timmis, Frost, & Ison, 2023). By examining the actual realised effects of mobility hubs, clearer conclusions can be drawn about whether their performance actually results in the desired output and thus can be considered as effective. Moreover, the research of Arnold et al. (2023) highlights the importance of performing evaluative research and acknowledges the need for a thorough evaluation of mobility hubs on their performance. Thus, in order to effectively assess the effects of mobility hubs, effective evaluation is crucial.

Additionally, when evaluating the performance of mobility hubs, it can be considered that predefined goals may vary widely depending on spatial and environmental context in which they are implemented. For example, Rongen et al. (2022) emphasize that mobility hubs in urban areas have different settings and goals than those in rural areas, where effectiveness is linked to different local goals. In this regard, Arnold et al. (2023) explains that the effectiveness of a mobility hub can be evaluated through the 4P framework, which stands for Purpose, Process, Place and Performance. This research highlights the need for context-sensitivity in evaluation and that hubs should be considered in their different properties. The study of Grigolon, Garritsen, and Geurs (2025) shares that it is not clear which elements within hubs, mobility-related or other, contribute to an improvement of integration of hubs.

Overall, this problem analysis results in the following problem statement which will be used guiding the research; The concept of mobility hubs is used within mobility development to enhance accessibility and sustainability by promoting a modal shift. However, the actual contribution to predetermined policy goals remains unclear due to the gap between theory and output. This is mostly dependent on the scarce knowledge on the performance and context-dependency of mobility hubs. Moreover, municipalities and developers often lack structured insights into how the performance of mobility hubs in regard to its objectives can be evaluated, where mobility hub context is included. This research will help understand the assessment of effectiveness of mobility hubs and improve their integration into mobility planning.

1.3. Research framework

The research framework serves the different components from which the research derives and thus presents the starting points for the conducted research.

1.3.1. Knowledge gap

Mobility hubs are increasingly promoted as instruments to achieve policy goals such as creating sustainable mobility and accessibility, systematic knowledge about their actual effectiveness in regard to these goals remains limited (van Nifterik et al., 2022). Current studies often focus on implementation aspects such as determining a suitable location (Blad et al., 2022). However, literature on effective performed evaluation after implementation to explore effectiveness of the objectives is scarce (Arnold et al., 2023). Therefore, there is little in-depth understanding of how different policy goals shape the design and realisation of hubs. Several studies highlight the importance of contextual aspects such as urban setting, different target groups and varying policy objectives. However, there is limited research available on how different contextual factors influence the performance of a mobility hub (Hachette & L'Hostis, 2023). Furthermore, studies focus on isolated performance indicators but give insufficient

attention to whether these indicators are actually reached. This research aims to address these gaps by conducting an evaluation framework which is applied to one case. As a result, tangible effects can be assessed after the implementation of hubs and contextual factors can be explored, with the goal to learn more on the effectiveness of mobility hubs and improve policy learning.

1.3.2. Research objective

The objective of this research is to develop a structured evaluation framework that aims to understand to what extent urban mobility hubs contribute to policy goals within development projects. Therefore, an evaluation of mobility hubs as a concept is assessed. This research objective can be categorized into different sub-objectives which are stated below:

- Conceptualise the underlying policy goals and objectives of urban mobility hubs, in order to create an overview of the desired effects of these hubs.
- Explore the different ways governmental bodies and developers currently monitor and evaluate mobility hubs.
- Identify indicators for assessing the effectiveness of realised urban mobility hubs through ex-post evaluation.
- Develop a structured evaluation framework which could be applied to an urban context using a selected case within Amsterdam.
- Critically reflect on the challenges and limitations of conducting ex-post evaluation of mobility hubs, due to contextual and functional varying aspects between hubs.

1.3.3. Research questions

The research is centred on assessing the main research question;

Main research question: *"How can the effectiveness of realised urban mobility hubs be assessed through an ex-post evaluation framework, in relation to their intended policy goals?"*

Within this research, the main research question will address the current knowledge gap on which way of evaluation can assess the effectiveness of realised mobility hubs. By conducting research on the performance mobility hubs, effectiveness can be determined through pre-determined goals and objectives. In order to address this main research question, different sub-questions have been set up that explore the different elements of the main research questions. The sub-questions are as follows:

1. *Which policy goals and objectives underlie the development of urban mobility hubs projects across the Netherlands?*
   Firstly, in order to establish what the desired effects of mobility hubs are, it will be identified which goals and objectives are set for developing urban mobility hubs. By gaining this insight, it can be identified what specific goals are aimed to achieve by the development of mobility hubs. Here, it is considered what type of mobility hub is aimed for in the goals, for this research the focus lies on urban mobility hubs. Therefore, lessons can mainly be learned for mobility hubs that fit within this context. By examining the variety and specificity of these policy goals across different projects, it becomes evident which strategic role mobility hubs play in broader area development initiatives. Within this analysis, there will be zoomed in on the municipality of Amsterdam and their goals, realising an in-depth analysis of this municipal strategy and vision.

2. *In what way do municipalities and provinces assess the performance of realised mobility hubs?*
   After the realisation of mobility hubs, performance of hubs can be monitored and evaluated in different ways. Governmental bodies such as municipalities and provinces are involved in the development of hubs and potentially assess whether they live up to their aspired objectives. This will give insight to what extent hubs are already evaluated and what different methods are available. Furthermore, this research question will give more context to which aspects are considered when exploring the effectiveness of hubs. Contributing to creating a structured framework in which lessons are learned from current principles and methods.

3. *Which indicators can be applied to assess the desired effects of a realised mobility hub?*
   With this sub-question, an analysis will be performed to determine which indicators can be used to assess the effects of a realised mobility hub. The aim of this research question is to give insight into how the effects of mobility hubs can be identified. Thus this will result in the indicators for which the evaluation of effectiveness on policy objectives can be explored. From these indicators, a focus will be put on how different contexts can adapt the framework to their most essential factors for indicating effectiveness. This will allow the study to further investigate a specific perspective of effectiveness rather than to explore multiple points of views on effectiveness.

4. *How can the effects of a selected urban mobility hub in Amsterdam be assessed through a developed evaluation framework?*
   After setting up the evaluation framework for mobility hubs, the framework will be applied to a selected mobility hub in Amsterdam. By applying the framework to a realised hub, insights can be gained on the different limitations of the framework. From these limitations, recommendations and future adjustments can be formed. Furthermore, by applying the created framework to a real case, it can be analysed what role the context of a hub could play in using the framework. This allows the framework to explore how context can influence the applicability of the framework and thus how one specific context can be analysed with the framework in practice. This research question will thus contribute to improving the framework by actually putting the framework into practice in a selected case application.
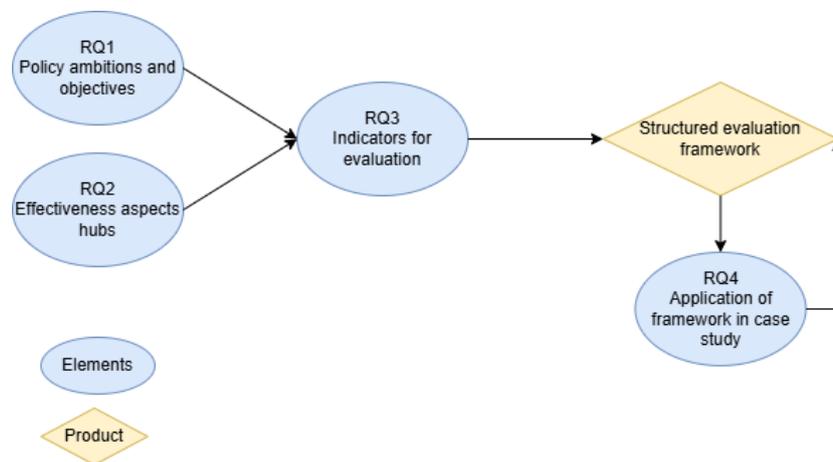
Figure 1.1: Research questions and their contribution

1.4. Scope
This research is limited to the study of mobility hubs within the Netherlands. The focus lies on hubs that have fully been realised, particularly those in urban dense areas and thus which can be considered as urban mobility hubs. The analysis firstly explores the different municipal strategies and visions across the Netherlands and later zooms in on the urban mobility hubs within the municipality of Amsterdam. This frame has been made to first explore the different goals, objectives and assumptions across different municipalities and to learn how strategies may differ. Afterwards, the focus on the municipality of Amsterdam ensures that more in-depth analysis can be performed on the effects of urban mobility hubs that (mostly) have the same municipal goals and objectives. From this in-depth analysis, recommendations can be made based on the result of these particular hubs and assumptions can be made for different contexts. Technical detailed aspects and financial considerations are excluded. In terms of methodology, the study uses a primarily qualitative approach through literature research and policy analysis, with additional empirical research through expert interviews and a case application. However, this will be supported by a quantitative evaluation framework, in order to identify both context-specific and transferable success factors.

1.5. Research relevance

This research will provide municipalities and policy makers with a clear understanding of how mobility hubs can potentially be evaluated in regard to their policy goals. Here, it will first be explored why the concept of mobility hubs has emerged and then a conceptualization will follow. This will give a practical overview of what is considered when developing a mobility hub and could serve as a guideline for developing hubs in different contexts. Additionally, through a policy analysis, the different goals and objectives regarding mobility hubs can be structured. This will lead to a better understanding of what is actually expected within hub development from a policy perspective. Furthermore, this research will provide valuable insights on how different municipalities and provinces currently assess mobility hubs, where lessons can be learned from other regions.

Besides from developing a practical overview of mobility hubs and illustrating the current situation, new perspectives will be presented in terms of evaluation. This allows municipal stakeholders to evaluate their developed mobility hubs and to see what contribution is made to societal challenges. By creating these insights, adjustments can be made in the development of hubs to create more effectiveness of hubs in achieving policy goals. Overall, this research can contribute to bridge the gap between theory and output of mobility hubs. This creates perspective on how mobility hubs can potentially be used as strategic tools for achieving societal goals within sustainable accessibility and optimizing public space. Nevertheless, it will provide valuable input for policy learning in mobility hub development.

1.6. Thesis outline

This research consists of nine chapters which are listed in the figure below. Firstly, Chapter 1 provides an introduction to the research, where the background, problem analysis, research framework, scope and practical relevance are presented. Afterwards, Chapter 2 presents the research methodology where the research design, different research methods and the data collection will be covered. Then, Chapter 3 creates the theoretical framework for this research. Exploring sustainable mobility, a conceptualisation of mobility hubs and provides a policy framework of existing policy documents. Chapter 4 presents the findings from the empirical research, where the results of the interviews are discussed and structured. Chapter 5 uses these insights to create an evaluation framework where the effectiveness of mobility hubs is explored. Within Chapter 6, a case application is performed where the evaluation framework is assessed at a selected mobility hub in Amsterdam. After analysing these findings, Chapter 7 discusses the implications of these findings and explores evaluation in mobility hub development while also including the limitations of this research. Chapter 8 concludes this research by answering the different sub research questions and the main research question. Finally, Chapter 8 will offer practical recommendations for governmental stakeholders and presents opportunities in future research.
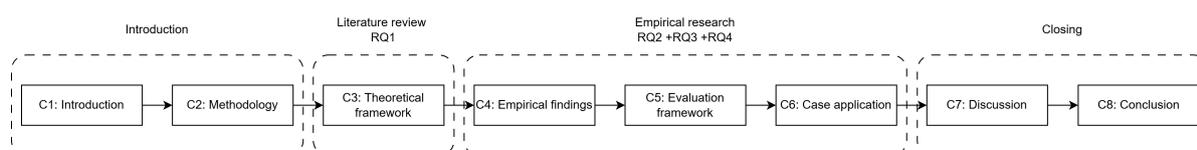

Figure 1.2: Thesis outline

2

Methodology

This chapter presents the methodology of the research on evaluating the effectiveness of mobility hubs. This research adopts a mixed-methods approach, where qualitative and quantitative research is combined. Hereby, a combination of a literature review, policy analysis, stakeholder interviews and a case application is conducted.

2.1. Research design

This research is structured around different research questions, that each aim to explore a different component related to the main research question with different approaches. In this context, the research focuses on how ex-post evaluation can be used to explore observable effects of mobility hubs after implementation. Furthermore, this evaluation is created by combining a qualitative theoretical framework with empirical research, which ultimately leads to the development of a framework. This mixed-methods design is suitable since it aims to integrate a qualitative contextual understanding with quantitative measurable indicators, where the combination of methods provides added value to the use of each approach on its own (Creswell & Zhou, 2016).

Qualitative research allows for a deeper understanding of behaviour and motivations underlying why mobility hub developments are employed in mobility policies (Bazen, Barg, & Takeshita, 2021). Furthermore, this is a semi-structured and exploratory study, given the relatively limited knowledge on performing ex-post evaluations for mobility hubs. Exploratory research is used to gain a new perspective in a field and allows identifying relevant evaluation dimensions for measuring effectiveness and exploring contextual factors (Jain, 2021). Consequently, semi-structured interviews are used as part of the qualitative approach, which allows the interviews to be focused while providing room to explore emerging ideas that come up during the interview to enhance understanding of themes (Adeoye◻Olatunde & Olenik, 2021).

This study uses both goal-based and theory-based approaches within evaluation exploration. The goal-based approach evaluates the observed effects and seeks to see whether these align with predefined goals (Leake, 1991). This goal-based approach is thus used to develop an evaluation framework, within which a method is created to explore the observed effects in relation to predefined goals. In addition, theory-based evaluation is used to identify and assess causal processes, which is suitable for this research to explore how mobility hub context might influence performance (Belcher, Davel, & Claus, 2020). The theory-based approach seeks to explain why certain effects occur by analysing contextual factors such as functions and the surrounding environment of the mobility hubs. By combining these approaches, the research assesses both outcome alignment and explanatory mechanisms.

Each research question contributes to gaining insights into the main research question "How can the effectiveness of realised urban mobility hubs be assessed through an ex-post evaluation framework, in relation to their intended policy goals?". Firstly, RQ1 focuses on a qualitative literature and policy review, in which different studies and documents are analysed to establish the policy framework of mobility hubs. Afterwards, RQ2 involves empirical findings derived from semi-structured expert interviews. Through

these interviews, the aim is to identify existing monitoring and evaluation methods that are currently used by municipalities to assess the performance of mobility hubs. The interview output is then used to create quantitative indicators that could reflect the potential desired measurable effects of mobility hubs addressed in RQ3. Finally, quantitative indicators and qualitative approaches are combined to create an evaluation framework and process for mobility hubs. In this framework, quantitative data and qualitative mechanisms will create an assessment of the perceived effectiveness of mobility hub performance with regard to the preset objectives. By doing so, RQ4 addresses the application of the created framework by conducting a case application in an urban context. Within this case application, the different contextual considerations of mobility hubs in relation to the developed framework can be identified. Overall, this research design ensures that theoretical concepts and objectives are combined with empirical findings. This contributes to filling the knowledge gap regarding how mobility hubs can be effectively evaluated by governmental stakeholders.

2.2. Literature review

Firstly, a literature review is conducted within the research in two different phases: the conceptualisation of existing mobility hub literature and a policy analysis of policy documents and strategies. Literature review is used as a method to gain more insight on the state-of-the-art of a concept and serves as building block of academic research (Snyder, 2019). As an initial step, sustainable mobility is explored to establish a strong basis for understanding the essence of achieving mobility transitions towards more sustainability. Afterwards, a conceptualisation of mobility hubs is performed in which the complex and varying nature of the concept of mobility hubs is assessed within the literature. This literature review was conducted using a structured approach, where the focus shifted from a broad perspective of sustainable mobility to a more specific search for mobility hub applications such as typology and contextual aspects.

For collecting the different studies, different sources of scientific reports such as ScienceDirect, Sage Journals, MDPI and Taylor & Francis Online were used. In order to find relevant references, keywords were used to explore different studies, these keywords, ranging from broad to more specific, included: "area development" "mobility development" "sustainable mobility" "mobility hub definitions" "mobility hub typology" "mobility hubs environmental aspects" "mobility hub ambitions" and "mobility hub evaluation". Most of the reports were conducted within a Dutch context due to the authors being Dutch and/or covering the Dutch development of mobility hubs. These studies were first selected, then assessed for relevance and subsequently relevant insights were selected and incorporated into the literature study.

After the general literature review on sustainable mobility and the concept of mobility hubs, a policy analysis was performed. Within this policy analysis a specific focus was put on the provincial policy documents of Noord-Holland and the municipal documents of Amsterdam, allowing for a clear focus on the selected case area. Firstly, general mobility plans for Noord-Holland and Amsterdam were explored to gain insight into key priorities present in the available mobility plans. After analysing the general mobility plans, a specific focus was put on mobility hub strategies and plans. Here, the different objectives and ambitions for the realisation of mobility hubs were explored. It must be noted that within this policy analysis, available documents are reviewed but that there is a possibility that important documents are overlooked and therefore not considered. The used documents have mostly been found on the websites of openresearch.amsterdam, Gemeente Amsterdam and Provincie Noord-Holland. Overall, the literature review and policy analysis provide a structured framework for RQ1 and serve as input for further analysis across the other research questions.

2.3. Ex-post evaluation

In mobility and transport planning and development, different methods exist to evaluate the effectiveness of interventions in relation to various policy objectives. Studies in literature distinguish different evaluation methods, offering different ways to evaluate policies such as mobility policies. Assessments conducted before the implementation of a project are quite common in ex-ante assessment as by means of for example a cost-benefit analysis (De Jong, Vignetti, & Pancotti, 2019). Nevertheless, ex-post evaluations, thus after implementation, are rather scarce and done infrequently but can give meaningful insights (De Jong et al., 2019). The report by De Jong et al. (2019) explains that ex post evaluation serves as a check of whether expected benefits are actually realised and provides insights

into which projects perform better or worse than expected and why. Maltese, Mariotti, and Oppio (2011) argue that studies have assessed indicators for shared mobility in urban areas but that little evidence is available, partially due to little ex-post evaluation. Therefore, this research conducts an ex-post evaluation to enhance policy learning and the development of mobility hubs.

2.4. Data collection

Besides the literature review, other forms of data are collected within the research. This data is collected through empirical research, which allows the research to assess existing mechanisms and methods and to create evaluation indicators for mobility hubs. Within this empirical research, additional methods of data collection include expert interviews and a case application.

2.4.1. Expert interviews

After the literature review, expert interviews are held to gain practical insights into mobility hub developments across the Netherlands. Experts are considered to have specialised and organisational knowledge, enabling access to insights of institutional practices rather than merely individual perspectives (Bogner, Littig, & Menz, 2009). In the context of this research, experts can share institutional knowledge regarding ambitions and practices in the field of evaluation. These expert interviews consist of two phases; exploratory interviews and in-depth interviews. Both interviews are semi-structured and have open ended questions, which allow for identifying new or refined insights. This combination of interviews first provides an overview of the situation in Amsterdam and then highlights the differences with other regions in terms of monitoring, evaluation and effectiveness.

The questions that have been asked to the interviewees can be found in Appendix A. This Appendix consists first of the interview procedure for the exploratory interviews and then the interview procedure of the in-depth interviews. Before conducting the interviews, a data management plan was set up and then approved by the TU Delft in order to ensure ethical and secure information collection and usage. Before starting each interview, informed consent was obtained from all participants according to a set up informed consent form. The data management plan and the informed consent form for the interviewees can be found in Appendix B.

Expert interviews are used as references throughout the research, where findings originate from different interviews. Citation of these interviews will be provided in superscript, where the number represents the number of the respondent. The corresponding numbers per interview are illustrated in Section 4.1.

Exploratory interviews

Firstly, exploratory interviews are held with representatives of the municipality of Amsterdam to explore the different applications and developments of mobility hubs in Amsterdam. These representatives work for the municipality of Amsterdam in the field of mobility hubs. Exploratory interviews are used within research to interact with a stakeholder to gain an initial insight into the subject matter(Jain, 2021). Within these exploratory interviews, interviewees get to elaborate on their role within the field of mobility hubs. The goal of these interviews is to gain new insights into how stakeholders experience the implementation of mobility hubs in Amsterdam. Here, they get to elaborate on their role and experiences within mobility hub development.

Moreover, the exploratory interviews provide the opportunity to identify new perspectives on development objectives after the policy analysis for Amsterdam. With regard to expectations and ambitions, it is explored whether different perspectives exist among the interviewed stakeholders. This could reveal varying perceptions regarding the expected performance of mobility hubs. In addition, the exploratory interviews illustrate the current availability of monitoring and evaluation practices of mobility hubs in Amsterdam.

In-depth interviews

Following the exploratory interviews, in-depth interviews are conducted with stakeholders from other municipalities, provinces and development organisations. In-depth interviews enable a comprehensive exploration of institutional practices and decision-making processes and allow for detailed understanding of mechanisms within different stakeholders' organisations (Bogner et al., 2009). The selection of interviewees follows from convenience sampling, where non random and non probability is used to

choose interviewees and this based on certain practical criteria (Etikan, 2016). For this research, participants are chosen based on expertise and relevance within the mobility hub field. Here, it was aimed to have variation in representations in order to gain perspective from different regions and different institutions. Participants were selected on reachability and availability.

The interviewees are selected to learn lessons from other municipalities, regions and provinces on how mobility hubs should be evaluated. The purpose of interviewing these stakeholders is twofold; firstly to explore ambitions, expectations and current developments and secondly to explore the performance and monitoring of realised mobility hubs. As for the expectations and ambitions, it is aimed to explore varying perspectives of different stakeholders across different regions. In addition, exploring the existing monitoring and evaluation practices illustrates the current evaluation situation. Not only are current practices explored, also the principles for evaluation are assessed in the interviews. By comparing criteria for an effective hub across stakeholder, lessons can be learned on what elements and indicators evaluation should contain.

2.4.2. Case application

After the interviews, an evaluation framework is formed through evaluation criteria and principles derived from the policy analysis and expert interviews. The case application applies the constructed evaluation framework in practice for a selected case in Amsterdam. By doing so, the different limitations and challenges of the framework can be identified and it can be explored whether the evaluation framework allows for the desired evaluation. The use of a case in research can provide learning in a detailed and contextualised real world phenomenon, which could be beneficial for testing a concept (Greenhalgh, 2025). In addition, by conducting the case application, it will be analysed how the context of a hub can influence the assessment. Hereby, the hub aspects as well as the specific hub objectives can be analysed within the framework. This can potentially illustrate how context can be considered within the evaluation framework and its process. However, the case application considers only one case within one specific context. Therefore, the application rather acknowledges context-dependency in application than claiming how to consider specific contexts in application.

Besides from putting the evaluation framework into a practical context to explore how evaluation can be performed, the hub will also be monitored in terms of usage aspects. Hereby, quantitative monitoring data will be collected to provide some insights into hub usage. This allows the research to learn how mobility hubs perform technically, in addition to the impact to policy goals and their societal impact. By performing this monitoring, feedback can be obtained on what aspects may be lacking with regard to the technical mobility hub usage performance. The specific case application protocol can be found in Chapter 6, where it is explained step by step how the framework is applied and why different considerations are made.

2.5. Data analysis

The data analysis process aims to systematically create a structured ex-post evaluation method for the performance of realised mobility hubs. This can be done by monitoring developed hubs and comparing them to the intended policy objectives identified in earlier stages of the research. To achieve this, a combination of qualitative literature analysis, indicator-based ex-post evaluation and a case application is used. This mixed analytical approach ensures both depth and consistency across the research design and strengthens validity throughout the research (Creswell & Zhou, 2016).

The first analytical stage involves a thematic analysis of the collected literature reports, policy documents and interview transcripts. Thematic analysis is used for analysing qualitative data, where patterns are identified, analysed and reported (Ahmed et al., 2025). All qualitative data regarding hub effectiveness derived from the interviews is coded through ATLAS.ti. Coding in ATLAS.ti is beneficial in qualitative data analysis for the identification of emerging patterns in in-depth interviews (Ñañez Silva, Quispe-Calderón, Huallpa-Quispe, & Larico-Quispe, 2024). This approach enables highlighting different key words that explain a certain objective or theme, this will then illustrate which indicators are mentioned for each objective. Additionally, the literature reports and policy documents supplement these identified indicators through existing themes and objectives from a theoretical perspective. Overall, this analysis allows for the identification of recurring objectives, themes and indicators of how effectiveness is interpreted by different stakeholders.

The second analysis stage focuses on the development of indicator-based ex-post evaluation. Indicators are often used for monitoring and evaluating developments, where indicators should be measurable, specific and relevant (Belcher, Claus, Davel, & Place, 2024). Here, the indicators are operationalised by translating the objectives into measurable variables, provided by the data from the interviews and policy documents. The evaluation framework is set up by using different components such as the identified objectives and operationalised indicators into a structured ex-post evaluation process. Therefore, the framework proposes a comprehensive method for ex-post evaluation of mobility hubs. By creating this process, guidelines can be given on how to assess the suggested evaluation framework.

Finally, the developed evaluation framework is applied in a selected case context. This application provides examining the proposed framework into a real-life context (Greenhalgh, 2025). The case application serves both as a test of the developed framework and as a means to explore context dependency in mobility hub evaluation. Overall, this multi-layered data analysis ensures the research assesses not only what developments have occurred, but also how and why these effects relate to the broader ambitions of sustainable urban mobility. The outcome of this analytical process will directly inform the discussion and conclusions chapters, where the main research question and sub-questions are answered.

3

Theoretical framework

This chapter will explore the theoretical concepts and principles that are useful when conducting research on mobility hubs. Firstly, the theory of sustainable mobility will be explored in order to gain perspective of why efforts such as mobility hubs are implemented within urban development. Since mobility hubs are developments that derive from the concept of sustainable mobility, the urgency of this concept will be assessed within existing literature. After exploring the necessity of creating sustainable mobility within urban development, a conceptualisation of mobility hubs will follow. In order to make meaningful statements on mobility hubs, it is useful to be aware of the different dynamics and aspects of the concept of a mobility hub. Therefore, this section will explore literature on the origin of a mobility hub, how a mobility hub can be defined, what typology exists, what different contextual aspects need to be considered and how far hub development currently is. By conceptualising the mobility hub concept, different applications and features can be used to make well considered statements. Furthermore, this chapter will analyse policy for mobility hubs, where different expectations and ambitions are explored. Additionally, existing policy documents will be analysed to form a better understanding of the policy drivers and goals within mobility hub development. Finally, this chapter will explore literature on existing evaluation and the different aspects of ex-post evaluation.

3.1. Sustainable mobility within urban development

Urban development faces challenges with transportation plans, by creating a more sustainable way of transportation while complying with needs as accessibility. Within this challenge, sustainable mobility is used as phenomena to tackle climate change issues while providing accessibility. Mobility hubs derived from this challenge and therefore the need of creating sustainable mobility is covered. This section will explore the concept of sustainable mobility and its background. Afterwards, the relation between sustainable mobility and liveability is explored.

3.1.1. Towards sustainable mobility

Sustainability is becoming an increasingly important topic due to climate change issues caused by greenhouse gas emissions. Rising temperatures are the result of greenhouse gas emission, resulting in climate change. In mitigating and battling climate change, environmental sustainability is a frequently used term. Khan, Nafees, Rahman, and Saeed (2021) define environmental sustainability as a concept where services and resources are generated without affecting the health of the providing ecosystem. However, in order to enhance environmental sustainability, big steps need to be taken in mitigating climate change. Therefore, different guidelines are set up to tackle sustainability issues worldwide, promoting less pollution and better conditions. One of these agreements is the Paris agreement, a legal binding treaty for mitigating climate change within the European Union. Moreover, the goal of this agreement is to limit the global average temperature rise to 2 degrees Celsius, preferably even 1.5 (European Council, 2025). Furthermore, the Dutch Klimaatwet (Climate Law) aims to have a decline of greenhouse gas emissions of 55 % by 2030 compared to 1990 and becoming climate neutral by 2050 (Ministerie van Algemene Zaken, 2025). Thus, it becomes evident that institutions are trying to reduce

greenhouse gas emissions to mitigate climate change. Human-caused greenhouse gas emissions especially need to be reduced to tackle the risk of creating climate change beyond adaptability (Liu & Cirillo, 2016).

Transportation has a significant impact on sustainability as a large contributor of air pollution and therefore has the urgency to improve sustainable practices (Andruetto, Stenemo, & Pernestål, 2024) . Within the EU, a share of 28.5 % of all greenhouse gas emissions is emitted by transportation in 2022 and this sector is the only one which is gradually increasing in emission levels (De Vos, 2024). Moreover, road traffic within the Netherlands was responsible for 17% of the total emissions in 2022, from which 57% was emitted by passenger cars (Centraal Bureau voor de Statistiek, 2024). Despite the disadvantages of private vehicles in terms of air pollution, the advantages of using a private car are rather convenient for daily life. The usage of a private car offers not only convenience and flexibility but also provides private space, making the transition to public transportation rather unattractive (Batty, Palacin, & González-Gil, 2014). In order to move towards sustainable mobility, a modal shift needs to be made towards more sustainable transportation methods such as shared or public transportation. Here, a modal shift can be explained as a change in transportation mode from one to another, which can be considered in by exploring changes in travel behaviour (Pearson et al., 2025).

Within this modal shift, a shift towards more sustainable transportation methods can contribute to achieving greenhouse gas emission goals. Furthermore, sustainable transportation refers to a minimization of greenhouse gas emissions within the mobility system, while improving resource efficiency and energy (United Nations Development Programme (UNDP), 2025). Sustainable transportation might include active transport, vehicles powered by renewable energy, public transportation and shared transportation (United Nations Development Programme (UNDP), 2025). In order to achieve this transition, incentives need to be created to make a modal shift towards more sustainable transportation modes. The demand for more sustainable transportation modes has been growing due to the motivation of mitigating greenhouse gas emissions and the urgency to align with set climate goals. Here, increasing societal awareness of the urgency of pressing environmental and climate related issues results in a different attitude towards sustainable mobility. However, measures taken for enhancing sustainability in individual daily mobility do not always result in high acceptance levels towards change, due to factors such as convenience and habitualization (Prillwitz & Barr, 2011). Moreover, egoistic values, subjective norms and perceived behaviour control can potentially influence choosing more sustainable mobility methods (Nogueira, Dias, & Santos, 2023).

However, governmental adjustments that are made to not only create sustainable mobility but also higher convenience potentially result in higher acceptance rates. In this light, the report of Nogueira et al. (2023) highlights that consumers are more likely to adopt more sustainable mobility options when broader public transportation networks are created, accessible pricing is reached and safer adjustments to for example bike lanes are achieved. Another governmental instrument that could potentially create changing mobility behaviours is financial incentives that create financial benefits for choosing more sustainable options. For example, in 2025 the Dutch government provides a 75% discount on motor vehicle taxes for electric cars (Ministerie van Algemene Zaken, 2025). Hereby, the government creates financial advantages of using more sustainable transportation methods. Not only does the government create incentives for adopting sustainable mobility, also businesses play an influential role. Companies can steer towards sustainable mobility within their business by creating a sustainable mobility culture. This can be achieved through different methods such as only allowing electric vehicles as lease cars, providing public transportation business cards and offering shared cars (Netherlands Chamber Of Commerce (KVK), n.d.).

Over the years, different modal shifts towards other transport modes have already taken place, through different scales and different contexts. For instance, different transportation methods have emerged such as e-bikes and scooters which have been adopted in daily life mobility. Moreover, the electric vehicles market has grown significantly, serving a solution for reducing urban air pollution and less usage of fossil fuels (Clairand, Guerra-Terán, Serrano-Guerrero, González-Rodríguez, & Escrivá-Escrivá, 2019). Not only private vehicles but also public transportation such as buses and taxis have the potential to take further steps towards becoming totally electric (Clairand et al., 2019). Besides creating new vehicles, other renewable sources of energy are emerging. Biofuels, biogas and green hydrogen might serve as promising renewable alternatives for the use of limited fossil fuels (Mizik, 2022). Overall,

innovations in transportation technologies result in a high potential towards sustainable mobility.

Not only are new modes of transportation and fuel options created, also usage of existing modes is enhanced. Shared mobility has become increasingly popular as a way of transportation. Within shared mobility, diverse forms are included such as car or bike sharing, on-demand rides, carpooling and private transit options (Guyader, Friman, & Olsson, 2021). Hereby, mobility on an "as needed basis" is created, which can serve as a remedy not only for reducing greenhouse gas emissions but also on reducing congestion and needed infrastructure, compared to private vehicles ownership (Guyader et al., 2021). Furthermore, another service which has developed over time is public transportation. Public transportation can offer the same benefits as shared transportation and has high potential in partially replacing private vehicle ownership. Investments have been made with the aim to increase capacity, reliability and affordability to promote usage of public transportation (Alhassan & Anciaes, 2025). However, despite these efforts, the benefits of private car ownership remain relatively high for users, which make taking a step towards a modal shift challenging. However, these efforts can still gradually shift attitudes and travel behaviour in order to reach sustainable mobility.

Overall, sustainable mobility has significant opportunities for tackling pollution issues. Improving current shared or public transportation could potentially result in a modal shift from private car ownership. Nevertheless, renewable alternatives for fossil fuels are emerging, potentially creating more sustainable alternatives for private vehicles. By seizing opportunities and innovations, the habitualization of private cars could be combatted to move towards sustainable mobility.

3.1.2. Enhancing liveability through sustainable mobility

Besides sustainability, liveability has become a relevant topic in urban development, dealing with spatial aspects while promoting a social environment. Sustainable mobility serves a crucial role in creating urban liveability, since mobility affects different societal aspects. Mobility is a cornerstone to liveability by creating sustainable, healthy and socially inclusive cities that can be reached partially through development of liveable streets (Harrison et al., 2022).

First of all, an important aspect of enhancing liveability is the efficient usage of space. Despite the growing pressure on available urban space, cities tend to continue accommodating private car growth (Gössling, 2020). As for now, cities are used for a significant amount of space for private modes of transport such as cars (Roca-Riu, Menendez, Dakic, Buehler, & Ortigosa, 2020). Private motorized vehicles create an overall lack of urban space through road infrastructure but also through parking facilities (Newman & Kenworthy, 2015). For example, Amsterdam's city surface is 13% in use as a parking area and cars take up approximately 50% of all street space in 2022 (Rebel-Group, 2023). Gössling (2020) thus highlights the importance of allocating more space to other transportation methods for urban planners. Sustainable mobility methods such as public transport or the prioritization of active methods such as walking or cycling could potentially reduce the lack of public urban space.

Not only do private motorized vehicles cause a lack of space, they also have disadvantages such as air pollution, safety issues and congestion (Gössling, 2020).Transportation is a significant source of noise and air pollution, which is often seen as a major constraint towards the quality of life in urban areas (Guo et al., 2020). By reducing car dependency and setting steps towards sustainable mobility, less transportation hindrance could be experienced due to cleaner air and less noise. Furthermore, the transition towards sustainable methods such as public transportation would also result in less congestion. By actively promoting sustainable mobility and reducing private car dependency, the disadvantages of cars can potentially be reduced.

Finally, sustainable mobility could potentially create more liveability by improving social aspects within urban spaces. Mobility can serve social practices by enabling people to interact through shared or public transportation. Furthermore, active modes of transportation such as cycling or walking create social interaction and contribute to safer and more vibrant neighbourhoods (Aldred & Jungnickel, 2013). In this light, when cars could partially be reduced from public spaces, more space is left to create social spaces such as parks or playgrounds. Here, it becomes evident that sustainable mobility does not only serve the goal of creating accessibility but could also potentially shape the quality of life in urban area development.

Overall, sustainable mobility creates opportunities for developing liveable cities, by addressing spatial inefficiencies, reducing environmental effects and enhancing social meeting places. Even though car ownership has dominated the mobility behaviour of many, shifting towards shared and active mobility modes as well as to public transportation creates sustainable and liveable mobility transitions. In this light, mobility can be explored beyond technical systems but can also be seen as social systems. Hereby, sustainable mobility provides healthier, more socially inclusive and resilient urban environments.

3.2. Conceptualisation mobility hubs

Mobility hubs are used as concepts within development projects, however the definition of mobility hubs varies significantly. Therefore, this chapter has the aim to conceptualise mobility hubs and create a state of the art concept. Firstly, this will be assessed through exploring different definitions that have been formed within academic literature. Afterwards, the origin from mobility hubs is analysed to create an understanding where mobility hubs derive from. As there are different definitions of mobility hubs, there are also different typologies. Different typologies will be discussed where hubs are differentiated on certain aspects. Finally, this conceptualisation will consist of the current situation on how different mobility hubs have been implemented.

3.2.1. Defining a mobility hub

Mobility hubs have been introduced as developments to enhance sustainable transportation while creating more accessibility. These mobility hubs can be defined in different ways, focussing on different aspects that they have. Moreover, mobility hubs can be defined as physical areas which offer a convenient transfer between different available transportation modalities that include shared transportation and possibly public or private transportation options (Blad et al., 2022). Furthermore, Coenegrachts, Beckers, Vanelslander, and Verhetsel (2021) argue that a shared mobility hub can be defined as a concept that clusters mobility services within a physical location, where different services, functions and facilities depend on different urban contexts which include policy goals. Here, it can be noticed that the definition of a mobility hub may vary in its context and can be multifaceted. Li (2020) adds to this concept of a mobility hub that it should integrate mobility functions to other facilities that offer a benefit to its surrounding neighbourhood, facilitating liveability to residents' daily life and travel.

Overall, it can be stated that hubs function as an easy access point for integrating different transportation modes. Here, consensus can be found in the mobility function of hubs. However, variation in the additional role of a hub to its surrounding and environment is present between different studies. For example, Trygg and Grundel (2025) highlight that a hub is strategically located in order to create a spatial and functional dimension as a proactive approach. Their report argues that mobility hubs can be used as strategic instruments to achieve transformative change such as reducing car dependency. In this perspective, studies highlight the strategic role of mobility hubs within urban area development. By implementing a mobility hub within an area and therefore potentially creating modal shifts, new opportunities arise for repurposing public spaces (Xanthopoulos et al., 2023). Not only would this then result in more accessibility but it would also enhance the quality of public space.

Thus, studies emphasize on mobility hubs not solely being a physical infrastructure that serves mobility purposes. Mobility hubs can therefore be seen as socio-technical systems where the integration of a new mobility system affects the social aspects of an area. The report of Arnold et al. (2023) shows that mobility hubs can result in modal shifts but also improve urban liveability in urban dense areas. Consequently, definitions vary mostly on the applications of mobility hubs. Where mobility hubs can be defined as physical multi-modal areas but can potentially also be seen as strategic instruments to achieve not only accessibility but also improve liveability in area development.

3.2.2. Origin of mobility hubs

The concept of mobility hubs can be derived from an earlier concept of creating multimodal transport junctions. Similarities can be found in other forms of transport nodes such as Park and Ride or Transit Oriented Development, which have the same context of creating areas designed to go from one transportation method to another (Rongen et al., 2022). However, the study of Rongen et al. (2022) states that little reflection has been performed on earlier concepts, where multimodal trips accounted

for approximately 5% of all trips within the Netherlands.

Furthermore, mobility hubs derive from the development of different shared mobility services that expanded rapidly. Here, cities were challenged with regulatory and planning issues to integrate shared mobility services within the city (Geurs et al., 2023). To address this development of shared mobility services, different concepts have been explored in transport planning (Geurs et al., 2023). The earliest concept of mobility hubs originates in Bremen in Germany, where the goal was to address shortage of parking spaces available by promoting shared cars (Arnold et al., 2022). This first example of a mobility hub with shared cars was called Mobil.Punkts and further developed within Germany and other countries to reduce private cars off the street and replace this with shared transportation (Arnold et al., 2022). Following this set example, other cities such as Amsterdam implemented the mobility hub concept within their strategic sustainable urban mobility plans (Rongen et al., 2022). Another closely related concept to mobility hubs is the Mobility as a Service (MaaS) principle. MaaS integrates various forms of private and public transport into a digital mobile service which can be used on demand (Meurs, Sharmeen, Marchau, & Van Der Heijden, 2019). This platform made the development of mobility hubs more advanced by providing a digital integration of services.

After the realisation of the first mobility hubs, different forms of hubs have been developed, varying not only in size but also in applications. Hereby, different focuses are created when realising mobility hubs, ranging from small scale neighbourhood hubs with minimal shared vehicles offered to large scale hubs such as railway stations (Geurs et al., 2023). Over the years, as has been elaborated within the previous section, mobility hubs were implemented to serve multiple socio-economic goals. Thus mobility hubs are created in mobility policies that aim to develop socio-cultural dimensions within mobility, resulting in different design choices and development strategies (Hansel, 2025).

3.2.3. Mobility hub typology
Different typologies of mobility hubs can be identified within literature, varying in scale, context and functionalities. Firstly, a distinction between hubs is made by the urban context in which a hub is positioned. The research of Blad et al. (2022) distinguishes this urban context firstly in target groups, where a distinction is made in a hub that serves only residents or also other groups such as visitors or commuters. Their research also distinguishes the transportation function, whether the hub improves accessibility or merely serves alternative options from car possession. Another aspect of their distinction is which modes are offered at the hub. Finally, their research results in the distinction of three different types of hubs; residential mobility hub, city mobility hub and regional mobility hub.

Another typology which can be used is the typology of Weustenenk and Mingardo (2022) where their research differentiates on different aspects as well. Within their research, the types of hubs are differentiated by transport modes, geographical location, facilities and services and scale (Weustenenk & Mingardo, 2022). A visualisation of this typology is presented in Figure 3.1.
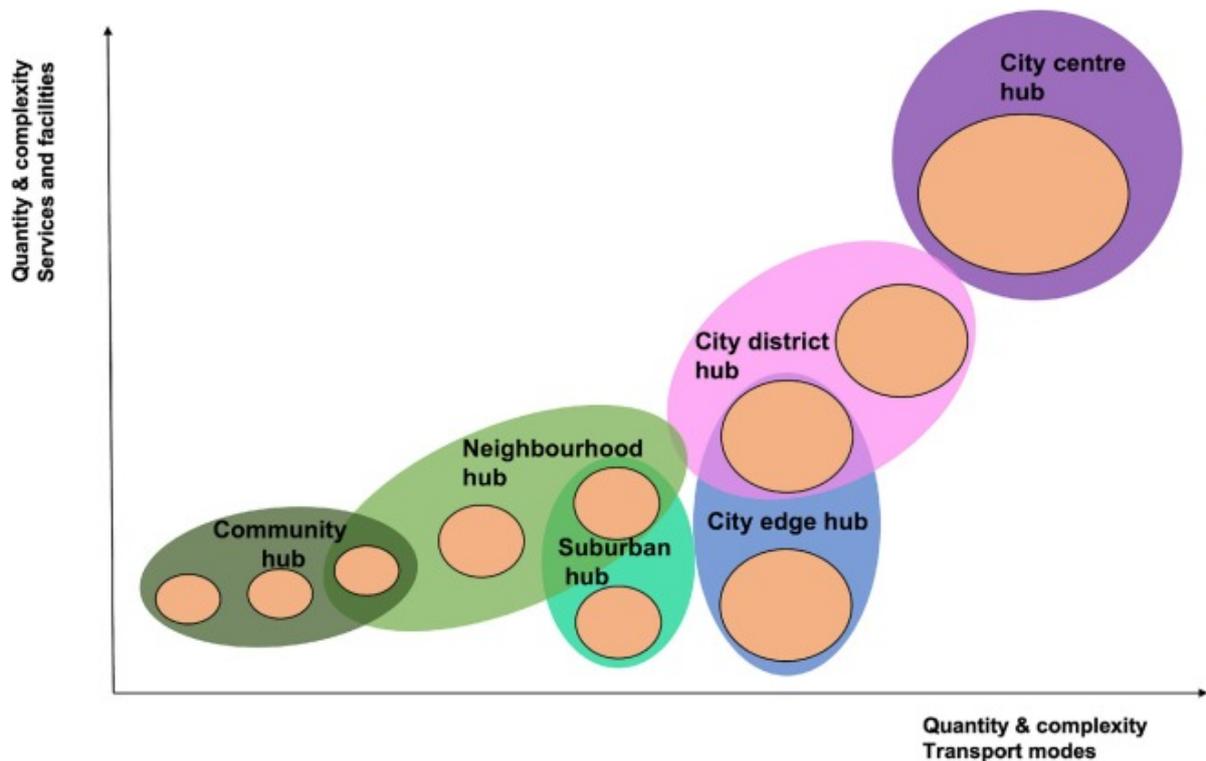
Figure 3.1: Mobility Hub Typology (Weustenenk & Mingardo, 2022)

Roukouni et al. (2023), propose a typology that primarily distinguishes hubs in urban context rather than applying other aspects. Their research results in five different urban contexts; city centre, sub-urban, emerging urban growth centre, historic centre and key (stand-alone) destination (Roukouni et al., 2023). Within this typology, hubs are allowed to have different attributes in terms of for example transportation function and scale. This allows two hubs that differ in size to still be considered within the same urban context. The study of Hachette and L'Hostis (2023) shows different typologies of hubs, one of the analysed typologies also combines the urban location and the function of a mobility hub into a typology of hubs. Their analysed typology distinguishes three different hubs; regional mobility hubs, community mobility hubs and neighbourhood mobility hubs. Here, regional mobility hubs are larger transportation nodes where multiple communities and active centres are linked. Community mobility hubs are explained as connectors to key regional destinations by providing interregional transportation links. Finally, Hachette and L'Hostis (2023) show neighbourhood mobility hubs which are local access points for low-density areas that offer connections to local or regional transport.

Overall, different typologies on mobility hubs exist within literature, differing in amount of types and attributes. Most of the typologies focus on diverse contexts, exploring for example differences in target groups or types of transportation modes offered. Especially urban context is an often mentioned aspect, where geographical location and size are explored as attributes. Studies vary in specificness of different types, where one study has six different types of mobility hubs and another has three. These different typologies show the dynamic and complex nature of using mobility hubs within (urban) development, where different aspects need to be considered for realisation.

3.2.4. Contextual aspects of mobility hubs
The environment of the mobility hub, functional aspects and the organizational setup make mobility hubs a rather complex concept. Mobility hubs serve different purposes depending on whether they are in different urban contexts (Roukouni et al., 2023). For example, a development project within an urban area differs from one within a rural area and a mobility hub placed within a residential area differs from one in a commercial area (Roukouni et al., 2023). According to Rongen et al. (2022), hubs must be designed according to policy objectives and adapted to their environment. Research of Hachette and L'Hostis (2023) states that there is no one-size-fits-all strategy when realising mobility hubs and that

each spatial context has its own opportunities and challenges.

The choice of location is important in hub development, influencing the design. Arias-Molinares, Xu, Büttner, and Duran-Rodas (2023) explore methodologies for prioritizing hub locations, including optimizing accessibility and using mathematical models to find the best locations due to points of interest. Physical site conditions such as topography, accessibility, land use and infrastructure also influence location choices for a multi-modal hub (Petrović, Mlinarić, & Šemanjski, 2019). Analysing environmental context helps determine the most suitable design, considering points of interest, demographics, land use and existing public transportation infrastructure (Arias-Molinares et al., 2023). Additionally, locating hubs in attractive open spaces is beneficial to encourage user interaction.

Urban contexts vary, with hubs in city neighbourhoods supporting shared mobility services due to the concentration of potential users (Czarnetzki & Siek, 2022), while suburban and rural hubs prioritize connections to regional transport and enhancing accessibility in lower-density neighbourhoods (Frank, Dirks, & Walther, 2021). Socio-economic factors like income and mobility behaviour also influence hub usage (Pangbourne, Mladenović, Stead, & Milakis, 2019). Integration within the surrounding land use and existing infrastructure is crucial for the hub's attractiveness (Trygg & Grundel, 2025). Moreover, Trygg and Grundel (2025) argue that services such as shops, restaurants or cafes can be added within the area to increase the attractiveness of the mobility hub.

The functional aspects of mobility hubs refer to the services and facilities they offer, which impact multimodal transportation. Smaller hubs may provide fewer services like car-sharing or shared bikes, while larger hubs like railway stations may also provide parking, public transport access, and charging stations (Geurs et al., 2023). Hubs may also provide amenities like repair stations, parcel lockers and food services (Arnold et al., 2022). The functions of a hub depend on its environmental and socio-economic context, with factors such as population density and demand influencing service offerings (Kamargianni, Li, Matyas, & Schäfer, 2016). For optimal functioning, seamless transitions between modes and integration of digital services like Mobility-as-a-Service (MaaS) are useful (Aydin, Seker, & Özkan, 2022)(Meurs et al., 2019). Moreover, Xanthopoulos et al. (2023) argue that creating more smaller hubs rather than fewer larger hubs may offer higher utility and coverage, thus their research states that it is not entirely beneficial to add more services to a hub.

The organizational aspects of mobility hubs, such as governance and decision-making, are key to their successful implementation. These hubs combine public and private services, making governance complex (Gavilan, 2020). The implementation process begins with defining objectives and stakeholder mapping (Taborda, Henriques, Carvalho, Magalhães, & Banza, 2023). Governance involves balancing public policy goals with private interests, requiring coordination across different policy levels (Coenegrachts et al., 2021). Pilot projects help test hub functionalities before scaling up (Õnne Kask, Plazier, Arts, Tillema, & Rongen, 2021). Clear governance structures and public participation are necessary to address the challenges of coordinating stakeholders and ensuring long-term viability (Hansel, 2025)(Arnold et al., 2023).

3.2.5. Current development of mobility hubs
During the years, mobility hubs have emerged from theoretical concepts to realised developments in many European regions and cities. Mobility hubs have been realised through municipal programmes and have emerged within mobility plans. Within the municipality of Rotterdam already 150 mobility hubs have been realised at the start of 2025, with the aim to scale up to even 200 hubs (The Future Mobility Network, 2025). The municipality of Eindhoven has also expanded their number of hubs from 19 to 50 within 2025 (Gemeente Eindhoven, 2025). This highlights the growing policy interest in using hubs as instruments within mobility plans in order to achieve policy goals such as creating a modal shift.

However, the total number of realised hubs remains rather scarce in regard to the ambitious strategies and plans. Some hubs are still in a pilot version where different services and functions are being tested to explore effective integrations (Õnne Kask et al., 2021). Mobility hubs have especially emerged in Europe, where hubs are used as instruments within mobility plans. With the Mobil.Punkt hubs in Bremen, many cities followed this development as an effort to reduce car ownership and to clear up urban space (Arnold et al., 2022). The Netherlands has incorporated mobility hubs in different municipal

and regional plans, highlighting how hubs are getting more popular.

Not only are not many hubs implemented within mobility developments, the size and integration within the infrastructure varies as well. Most currently implemented hubs are small-scale and often lack full integration with for example Mobility-as-a-Service platforms, limiting potential for systematic mobility transitions (Pangbourne et al., 2019) Not only do hubs differ in size, also in implementation due to different contexts. Therefore, no standardized implementations are available for hubs under certain contexts and settings. Nevertheless, despite these challenges, the concept of mobility hubs has gained policy interest by offering potential for actively using mobility hubs to promote modal shifts.

3.3. Policy framework mobility hubs

This section will create a policy framework of the development of mobility hubs in urban settings. Firstly, this section will explore the expectations and ambitions of mobility hubs, to address where the envisioning of mobility hubs as an instrument derives from. Afterwards, the available policy documents and strategies will be analysed to form an understanding of how municipal bodies have translated mobility hubs into actionable plans and strategies. Finally, different realisations of policy strategies and plans will be explored.

3.3.1. General expectations and ambitions of mobility hubs

Different views and expectations exist around the performance of mobility hubs after development. Within this analysis, different objectives have been categorized, to give an overview of the different expected applications of mobility hubs in literature.

Enhancing multimodal transportation
Since the main function of a mobility hub is to create an area where multiple transportation methods can be used, the enhancement of multimodal transportation is a consideration. Aydin et al. (2022) argue that mobility hubs should create seamless transfers between public transportation and shared transportation. Moreover, Geurs et al. (2023) emphasize that the development of hubs has the core performance of creating multimodal integration. Creating multimodality has different potentials which will be elaborated later on. Furthermore, Xanthopoulos et al. (2023) state that hubs create multimodality through linking traditional public transportation to emerging new shared modes of transportation.

Improving accessibility
One of the benefits of creating multimodality is the enhancement of accessibility in areas. The report of Frank et al. (2021) highlights that especially in rural and suburban contexts, hubs could potentially create better accessibility to public transportation. Within this article, they elaborate that low-density areas can be linked to regional networks more easily, by providing first-and-last mile opportunities (Frank et al., 2021). In this light, Martinez, Macharis, and Keserü (2024) argue that hubs could reduce accessibility gaps, since connections could be strengthened for disadvantaged groups and areas with low service offers.

Reducing car dependency
Since more modes of transportation can be offered such as shared bikes or scooters, car dependency could potentially be reduced through the implementation of mobility hubs. Roukouni et al. (2023) explain that through the extended offer of accessible alternatives, hubs could reduce the usage of private cars which contributes to sustainable mobility transitions. In this way, hubs can create a shift in current mobility systems by reducing reliance on private cars. Stadnichuk, Merten, Larisch, and Walther (2024) explain that this shift from private car ownership to shared mobility has the most potential in urban dense areas. Since urban dense areas like city centres have limited space for parking cars and mobility hubs could reach many residents, a potential is created to shift away from private car ownership (Stadnichuk et al., 2024). Overall, by offering different accessible transportation modes, a potential modal shift from private car ownership could be aspired.

Contributing to climate goals
Sustainable mobility is a key policy objective, as has been explained, to achieve climate goals. Since mobility is a key player in pollution of greenhouse gas emissions, different more sustainable options can

be explored. Since mobility hubs offer public transportation and shared mobility options, development of hubs could potentially lead to less pollution. Moreover, Bencekri et al. (2024) argue that mobility hubs are expected to create low emission nodes, by centralizing shared mobility and electric vehicles potentials, a significant contribution to emission reduction strategies could be realised. That hubs could be used as a political instrument to achieve climate goals is also explained in the article of Hansel (2025). Hereby, Hansel (2025) envisions hubs as a part of sustainable transitions through governance interventions, where long-term contribution to sustainability objectives could be created.

Creating multifunctional community spaces

Not only are ambitions set on sustainability or accessibility efforts, also on the creation of multifunctional areas within public spaces. For example, the study of Arnold et al. (2023) notes that hubs will not only function as transportation nodes but should also be offering supportive services to embed into community spaces. Therefore, the ambition is created to develop areas where public space is designed to integrate mobility within daily life services. Within this ambition, Taborda et al. (2023) highlight the necessity for people-centred design approaches to reach integration of hubs within daily life activities and services.

Overall, most expectations and ambitions that underlie the development of mobility hubs are interrelated. Mostly due to the offering of multimodal transportation options, more sustainability and accessibility can be created. However, in order to achieve most of these ambitions, especially in terms of sustainability, an active modal shift is required.

3.3.2. Available policy documents and strategies

Within this section, the different available policy documents and strategies regarding mobility hubs in urban context are analysed. Since the case application will be performed at the municipality of Amsterdam, different documents from this municipality and the province of Noord-Holland will be explored. Through this analysis, a clear overview can be created on what mobility plans are relevant and how mobility hubs support these different plans. Therefore, firstly a general mobility strategy analysis will be performed, from which afterwards an in-depth analysis on the role of mobility hubs will be performed.

General mobility plans

Within these general mobility plans, a focus will be put on objectives that are relevant for the development of mobility hubs. Therefore, it should be noted that several parts of these plans are highlighted and are not the only relevant points within the mobility plan. It should also be noted that these plans are translated to this report partially by interpretation. Thus, this leaves room for misinterpretation or wrong translation. Nevertheless, information insights will be gained from these documents.

Mobiliteitsaanpak Amsterdam 2030

Firstly, the Mobiliteitsaanpak (Mobility Approach) Amsterdam 2030 represents the headlines of the mobility policy approach for the upcoming years. This policy document has been set up by the city council in 2013, as a framework for the period until 2025. Within this document, the aim was to envision how Amsterdam would be kept accessible by putting attention to improving the public open space. Overall, the Mobiliteitsaanpak Amsterdam 2030 outlines the strategic vision to maintain Amsterdam's accessibility while improving the quality of public space, considering an increasing mobility demand and spatial scarcity. This document emphasizes the transition towards 'more mobility with fewer resources and less space demanding'. Key objectives are set up that include creating a low car traffic urban environment by 2025, reallocating street space from parking to public and residential use and enhancing the liveability in the city. Here, the policy links mobility management with spatial quality, where infrastructure reorganization is aimed for. This need for integrated solutions derives from challenges such as parking pressure, lack of pedestrian priority and congestion. Within the policy's implementation measures, different efforts are set up to achieve this ambition. These efforts have a focus on reducing on-street parking, promoting indoor parking solutions and optimizing public transport with peak-hours. All potentially resulting in the dis-encouragement of car use and optimization of multimodal accessibility.

Uitvoeringsagenda Mobiliteit

The Uitvoeringsagenda Mobiliteit (Implementation Agenda Mobility) has been set up by the city council in September 2015 and builds on the MobiliteitsAanpak 2030. Therefore, this agenda also focuses on

creating accessibility while maintaining attractive public space. This agenda states that doing nothing is not an option and emphasizes the growing pressure and the scarcity of public space. Moreover, this agenda provides some more specific cases on how to tackle certain challenges. Within this research, only the main objectives are highlighted rather than specific region adjustments. Within this document, the objective of maintaining accessibility while expanding high-quality public space is also emphasized. Here the essence of 'doing nothing is not an option' shows the spatial pressure of mobility in the city. Further, this agenda is structured into three key priorities: creating more space, ensuring smooth traffic flow and connecting the city. These priorities focus on reclaiming space for pedestrians and cyclists through reducing traffic, while promoting car-sharing and park and ride facilities. Furthermore, connecting the city is explained by spreading the crowdedness while expanding high quality public transportation.

Uitvoeringsprogramma Mobiliteit 2024-2030

The Uitvoeringsprogramma Mobiliteit (Implementation Programme Mobility) 2024-2030 consists of key visions and objectives that are related to the mobility measures in the region of Amsterdam. This document has been written by the Vervoerregio (Transporation Region) Amsterdam in 2023. The document follows the Beleidskader Mobiliteit which is the strategic policy document of Vervoerregio, the Uitvoeringsprogramma Mobiliteit serves as the implementation framework of this policy. Moreover, this document explains prosperity in the 'broad sense', focussing on a mobility policy that is translated into five key themes. The main objective is to create a sustainable accessible region which shifts from public transportation to public mobility. Public mobility can be achieved through investing in bicycles, pedestrians, shared mobility and Mobility-as-a Service (MaaS). Thus, the broad prosperity is translated in the following themes; accessibility, sustainability, traffic safety, health and inclusivity. Here the five different themes influence the transition towards public mobility. Furthermore, the document contained specific implementations in regard to housing and environmental efforts, these implementations fall beyond the scope of the research.

Programma Deelmobiliteit Amsterdam

The Programma Deelmobiliteit (Programme Shared Mobility) Amsterdam was set up in 2021 to address plans regarding low car traffic by facilitating shared mobility. Shared mobility has risen as a strategic element by the municipal council and the Vervoerregio Amsterdam through different policy documents such as Beleidskader Autodelen (Policy Framework Carsharing) 2021 and Nota Deelmobiliteit (Nota Shared Mobility) 2019. Therefore, the Programma Deelmobiliteit was set up to realise a strategy for implementation. Different measures were put together with the aim of using shared mobility as a key alternative for mobility within the city. In order to achieve this, preconditions within the document are that enough vehicles are available, that they are accessible when needed, that they are payable and finally that possible users are aware of their offer.

This document describes shared mobility as a pillar for Amsterdam's mobility transition through different measures. Moreover, the document aims that shared transportation should thus be made available, accessible, affordable and that potential users should be made more aware to create a reliable alternative for private car ownership. The agenda promotes an integration of shared mobility within the physical infrastructure as key nodes for multimodal connectivity. Explicit ambitions as to make all shared vehicles emission-free by 2025 and to embed shared mobility as a guideline in area development, shows a start from initiative towards implementation. Overall, this document operationalises certain policies such as reducing car use to integrate with shared mobility in urban planning and travel behaviour

Mobility hubs strategies

After this analysis of general mobility plans regarding the mobility systems in Amsterdam, the contribution of mobility hubs to these visions is analysed. This is assessed by analysing different mobility hub strategies and plans, in order to create a vision of how mobility hubs could contribute to mobility policies.

Hubstrategie provincie Noord-Holland

The Hubstrategie provincie Noord-Holland (Hub Strategy Province North-Holland) was developed in 2023 and analyses how mobility hubs could be implemented as an instrument to realise a mobility transition. This document aims to create accessibility, liveability, safety and health in a rapidly growing

province, where pressure is put on the mobility system. Hubstrategie provincie Noord-Holland envi-
sions mobility hubs not as a goal on its own but as a useful development to enforce the mobility system.
Within this strategy, six different hub categories are set up; varying in reach and urbanism. Therefore,
different visions and strategic objectives have been set up within the document. The four dimensions
that explore "prosperity in the broad sense" are accessibility, liveability, safety and health. Per dimen-
sion a set of goals has been formulated, these objectives can be used as indicators to analyse the
impact of mobility hubs on the wellbeing of people. The document states that the influence of mobility
hubs could have indirect or direct effects towards the set goals. Moreover, this influence is considered
dependent from other effects and factors within the larger mobility system. Within the document three
development strategies are set up; to build a comprehensive network, to solve bottlenecks and to inter-
vene in new developments. The document emphasizes the active steering role that the province could
take for region hubs. Finally, it addresses monitoring as an important component to reflect on potential
improvements and adjustments for the performance of hubs.

Hubvisie 2021
The Hubvisie (Hub Vision) 2021 of Amsterdam has been set up by the College van Burgemeesters &
Wetgevers (Council of Mayors and Legislators) in December 2021. This document offers perspective
and course of action to make the city accessible, liveable and available in a period of growth and
increasing complexity. Furthermore, this vision is created where mobility hubs are crucial instruments
for realising an attractive and liveable city. Hubvisie 2021 acknowledges the lack of space, mostly
caused by cars and therefore investigates hubs as a tool to create space. Previous initiatives that
have been taken to reduce the car pressure within the city which are mentioned in this document are
parking rates, P+R facilities and investments in public transportation and cycling routes. These efforts
in redevelopment have been proven efficient according to the Hubvisie 2021, resulting in a decline
of short car rides of approximately 60 percent in 20 years. The municipality steers towards a further
mobility transition by focusing on different separate transitions;

1. Transition towards a more space-efficient, lighter and cleaner mobility within the city.

2. Transition from ownership towards usage.

3. Transition from unimodal travels to multimodal travels.

Overall, the Hubvisie Amsterdam 2021 marks mobility hubs as core instruments within the mobility tran-
sition in Amsterdam. Hubs are explained as social assets that can enhance public space quality while
safeguarding accessibility. To achieve this, three principles are aimed for in the development of hubs.
Hubs should be recognisable & unambiguous, connected & interchangeable, reachable & accessible.
Nevertheless, the following design principles should therefore be implemented; recognisable, inclusive,
attractive, predictable, reliable and flexible. The Hubvisie recognizes the different aspects that hubs
might have and how they would serve different goals. Furthermore, the Hubvisie distinguishes hubs on
different aspects and functions, making sure that each hub serves a more specific role in development.
For example, the buurthub (neighbourhood hub) is illustrated in Figure 3.2 where goals, functions and
other features are mentioned.

Figure 3.2: Hubvisie example hub description(Gemeente Amsterdam, 2021)

Ontwikkelprotocol Mobiliteitshubs Sloterdijk 1 Zuid

The Ontwikkelprotocol Mobiliteitshubs (Development Protocol Mobility Hubs) Sloterdijk 1 Zuid has been set up by the municipality of Amsterdam in 2021 and describes the iterative process of development to realise mobility hubs in Haven-Stad. This is a specific sub-area where so-called block hubs, hubs at block level, have been designed. Furthermore, this protocol has been set up with the ambition for urban densification and sustainable mobility. As a result, Sloterdijk 1 Zuid serves as a pilot project for the area of Haven-Stad.

Summarized, the Ontwikkelprotocol Mobiliteitshubs Sloterdijk 1 Zuid provides a detailed design and implementation framework for block-level mobility hubs. The protocol serves as a pilot project where policy ambitions are translated to more concrete spatial design principles. For example, the protocol creates a low-car vision where the modal split of car use is only 15%. Within the document, the STOMP principle is used which shows the order of prioritisation of modes of transportation within sustainable

accessibility. STOMP stands for the order Stappen, Trappen, Openbaar vervoer, MaaS and Privé auto (Walking, Cycling, Public transportation, MaaS and Private car). The guiding principle STOMP is established per block and moves away from on-street parking and towards indoor parking facilities. The document also introduces quality impulses where quality improvement is reached for certain modes of transportation, non-mobility functions are added and quality is improved per block. Minimum space per mobility mode is mentioned to ensure that the space is reorganised efficiently in regard to the set goals. Overall, the protocol aims to expand functionalities while minimizing outdoor space usage. This enables mobility hubs to reorganise the public space in which they are developed.

Figure 3.3 illustrates the time line of the analysed documents, where the main principle of each document is stated. This shows a gradual shift from sustainable mobility to shared mobility to mobility hubs within in analysed policies.

2013 Mobiliteitsaanpak Amsterdam 2030:
Foundation for sustainable mobility

2015 Uitvoeringsagenda Mobiliteit:
Tangible priorities for mobility

2021 Programma Deelmobiliteit:
Shared mobility as a key instrument

2021 Hubvisie Amsterdam:
Mobility hubs integration plan

2021 Ontwikkelprotocol Mobiliteitshubs Sloterdijk Zuid:
Pilot project for shared mobility integration

2023 Hubstrategie Provincie Noord-Holland:
Regional network strategy

Figure 3.3: Time line of analysed documents

3.3.3. Findings of strategies and plans
Overall, the development of urban mobility hubs in Amsterdam and the Province of Noord-Holland reflect a mobility policy evolution over the years. This is formed from broad ambitions for sustainable mobility to more concrete spatial and operational frameworks where multimodal mobility is promoted. Firstly, the Mobiliteitsaanpak Amsterdam 2030 (2013) served as a foundation for linking accessibility to quality of public space and the introduction of a low car traffic city, aiming for space-saving and

sustainable solutions. The Uitvoeringsagenda Mobiliteit (2015) translated these ambitions into tangible priorities; creating more space for active modes, improving traffic flow and connecting the city through public transport and P+R networks. These ambitions collectively framed the early starting points of the developments of mobility hubs as instruments to enhance accessibility while creating sustainability and liveability.

Later on, policy attention gradually shifted towards shared and flexible mobility options. Here, the Programma Deelmobiliteit (2021) presented shared mobility as a key instrument to reduce car ownership and to integrate multimodal mobility within travel behaviour. Within these operationalisation objectives such availability, accessibility and affordability were key pillars. Furthermore, the Hubvisie Amsterdam (2021) elevated mobility hubs as a central role within the aimed mobility transition. Explicitly connecting them to three systemic shifts: from ownership to use, from unimodal to multimodal travel and towards lighter and cleaner mobility. Hubs were redefined not only as infrastructural nodes but as spatial and social assets that improve urban quality and inclusivity.

The Ontwikkelprotocol Mobiliteitshubs Sloterdijk Zuid (2021) demonstrated how these policy goals could be operationalised in practice. Therefore, functioning as a pilot project for integrating shared mobility in dense urban redevelopment. It established concrete design standards and quantitative indicators. These indicators were; creating a modal shift, changing parking norms and space relocation, therefore illustrating how policy ambitions translate into measurable outcomes. Finally, the Hubstrategie Provincie Noord-Holland (2023) expanded the focus from the municipal to the regional scale. Embedding hubs within a province-wide network strategy that aims to enhance accessibility, liveability, safety and health across diverse hubs into one structured framework. The inclusion of monitoring and measurable policy dimensions formulated a more developed phase in mobility hub policies, oriented towards evaluation and adaptivity.

Together, these policy documents reveal an evolution towards integrated and spatially prioritised mobility planning. Mobility hubs have evolved from abstract policy concepts into more concrete, evaluable instruments. These instruments explore the principles of sustainable accessibility, space efficiency and relocation and change in travel behaviour. For this research, these developments form an explored policy framework through which the effectiveness of realised mobility hubs can be evaluated. Where preliminary policy goals can be linked to measurable indicators and potential observed effects.

Over time, the focus has shifted from mobility supply to mobility performance, requiring a mobility transition. Also, from infrastructure expansion to space reallocation, in order to enhance the quality of public space. These transitions do not only establish the political and conceptual ambitions of mobility hubs but also provide a set of evaluative dimensions; sustainable accessibility, spatial quality and inclusive cohesion. These dimensions, derived from successive policy frameworks, form the basis of the policy evaluation framework for this research. They reveal the underlying policy logic against which realised hubs can be assessed:

- Goal orientation: how hubs reflect established ambitions for sustainable accessibility, spatial quality and inclusive cohesion.
- Means and mechanisms: how design principles, governance models and shared mobility systems operationalise these ambitions.
- Expected effects: which observable outcomes, such as reduced car dependency and improved public space quality serve as indicators of effectiveness.

By operationalising these evolving ambitions into a structured set of policy-derived objectives and indicators, this research can evaluate to what extent realised urban mobility hubs align with or deviate from their intended goals. In this way, the policy development from 2013 to 2023 does not merely provide contextual background, but it also contributes to the foundation for the operationalisation of evaluation.

3.4. Evaluation in literature

As for now, there are not many studies that explore the effect of mobility hubs, such as the impact on the mobility behaviour of potential users (Stadnichuk et al., 2024). The first Mobil.Punkt was analysed by Miramontes, Pfertner, Rayaprolu, et al. (2017) where they analysed users on their acceptance and the influence in mobility behaviour. Here, participants revealed that even though they believe that mobility

hubs could replace private vehicle ownership, 75% believe that the actual replacement of trips would be minimal (Miramontes et al., 2017). However, the study states an observation that public transportation trips have increased at least partially due to the implementation of hubs. The report of Stadnichuk et al. (2024) mentions other analyses on hubs where conclusions are drawn on characteristics of users of mobility hubs. However, the report states that not much research has been performed on the mobility behaviour after implementation of hubs. Nevertheless Stadnichuk et al. (2024) share that integrating shared mobility services influences mobility behaviour, rather than merely the implementation of mobility hubs alone.

As has been mentioned, evaluation on the performance of mobility hubs is rather scarce, where evaluation is mostly centred on implementation rather than performance. Nevertheless, one recent monitoring report with quantitative data on the use of shared mobility at hubs has been set up by the Rijksoverheid (National Government) in 2024. This monitoring report is called Monitoring en Evaluatie Deelmobiliteithubs Jaargang 2024 (Monitoring and Evaluation Shared Mobility Hubs Year 2024) (Ministerie van Infrastructuur en Waterstaat, 2025) and is a rare example of monitoring data within the Netherlands which sets a step towards ex-post evaluation. Even though the report mostly shares user statistics, it is an useful reference for comparable evaluations. The results of this analysis will be shared below, where the scope will be elaborated, the aim of the analysis and some insights.

Within the analysis 321 shared mobility hubs have been monitored in different cities within the Netherlands, most of middle large size and mostly located in urban areas. In these areas, car ownership was relatively low and the hubs are mostly located close to trams or bus stops. The monitoring revealed that per hub approximately 43 rides were made with shared mobility, it is mentioned that average was raised significantly by some hubs with large usage numbers. Moreover, the report mentions that the 10 percent highest hub usage has an average of 239 rides per week, while the lowest 10 percent only has an average of 2 rides per week. Here, the conclusion was drawn that shared mobility was used the most at larger hubs in high density urban areas, where car ownership is low and hubs are closely located to public transportation services.

Overall, the goal of the analysis was to gain insight into the use of hubs against different factors. Furthermore, the report elaborates on the different contexts in which hubs function that could affect the use of shared mobility hubs. In this light, it is considered of importance that causal relations or not drawn too fast between results and influencing aspects, since many variables correlate such as car ownership and urbanisation rate. Beyond these findings, it is mentioned that hubs are analysed on the environmental aspects of hubs and not on the users of shared mobility. Finally, the report states that in the coming years conclusions will be refined with the addition of more hubs and more differentiation between hubs.

3.5. Conclusion

This chapter contributes to exploring a theoretical and policy framework in which the considerations for evaluating mobility hubs can be made more insightful. By combining literature on sustainable mobility with a conceptualisation of mobility hubs, the origin, nature and functionalities of mobility hubs are explored. This literature revealed that mobility hubs can be considered as complex and dynamic interventions, due to contextual aspects such as size, location and functionalities. Insight was gained on how mobility hubs differ and that this diversity should be considered within evaluation.

Furthermore, policy objectives were analysed on the development of mobility hubs. Hereby, general expectations and ambitions such as improving accessibility, contributing to climate goals and creating community spaces illustrated how mobility hubs are multi-functional developments which serve multiple goals. These ambitions and goals make sure that mobility hubs are multi-purpose interventions which affect accessibility and liveability of areas, rather than merely offering a new mobility infrastructure. Therefore, mobility hubs are positioned in theory as strategic instruments to support multiple societal goals. Further, various policy documents and strategies were reviewed in the scope of Amsterdam and its province, which revealed the gradual introduction of shared mobility and mobility hubs in mobility plans. It became evident that mobility hubs are integrated in structural plans such as the Hubvisie. Overall, the different thematic goals that have been formulated after the policy analysis are sustainable accessibility, spatial quality and inclusive cohesion. Here, each theme represents objectives that target

a specific societal impact.

Nevertheless, the policy review also highlighted that the objectives tend to be broadly and normatively formulated. This leads to less concrete and measurable evaluation criteria, which is therefore an identified gap within existing literature and policies. Additionally, context dependency should also be considered in evaluation, where their specific intended function, scale and contribution to goals depends on urban density, policy ambitions and spatial integration. This complicates applying uniform effectiveness criteria and principles for the evaluation process. Overall, Chapter 3 combines literature and relevant policy documents and objectives to gain insight of the purpose that mobility hubs serve and their underlying expectations and ambitions.

These insights can be used as underlying guidelines for addressing evaluation for mobility hubs. Chapter 3 contributes to answering RQ1: *Which policy goals and objectives underlie the development of urban mobility hubs projects across the Netherlands?*. Further, the section on evaluation in literature shows that even though some evaluation is performed, this evaluation can be considered as limited. By using the gained insights, principles are established which should be taken into account for in practice evaluation of mobility. This chapter lacks knowledge on how theoretical ambitions and policy objectives are interpreted in practice by involved stakeholders. Also, the priorities in the policy agenda regarding mobility hub development remain rather unknown, where relevance is not yet explored. In this light, this chapter lacks to establish insight on specific measurable aspects that would assess the effectiveness of the development. This knowledge gap in the explored theoretical and policy framework highlights the need for empirical research. Therefore, the next step in this research is to test and deepen this theoretical framework through the empirical insights from the expert interviews, as elaborated in chapter 4. This allows the research to investigate how effectiveness is interpreted in practice and which evaluation needs and challenges are experienced by involved and responsible stakeholders.

4

Empirical findings: mobility hub exploration

Within this chapter, the results from the expert interviews are presented. This data illustrates the different insights and perspectives derived from the interviews. Accordingly, a data analysis is performed where different themes and principles are discussed. Firstly, the results from the exploratory interviews are analysed where the current mobility hub development in Amsterdam is discussed. Then, the results from the in-depth interviews with other stakeholders are analysed. These result include the current developments across the Netherlands as well as the available monitoring methods and mentioned evaluation procedures and principles.

4.1. Expert interviews set up

Below, Table 4.1 is presented, showing the different interviews conducted in this research. This table illustrates which respondent represents which organisation and when the interviews were conducted. Here, the selection was made for three different additional municipalities, three different provinces and two different developers. This selection was made to create a range of different perspectives from different regions. Further details on the selection method for the respondents can be found in Chapter 2. The number of interviews was limited due to lack of response from certain municipalities and time constraints within the research. Nevertheless, sufficient information has been collected for the analysis in this research. This analysis aims to explore the policy on mobility hubs from the view of involved stakeholders, to further deepen the literature and policy framework from Chapter 3. The number of each respondent is used in the references of the interview. The reference of an interview is presented in superscript, for example example[1] corresponds with the interview of respondent 1 which is one of the representatives of the municipality of Amsterdam.

Table 4.1: Overview of interview respondents

Respondent	Representation	Interview date
1	Municipality of Amsterdam	29/10/2025
2	Municipality of Amsterdam	29/10/2025
3	Municipality of Rotterdam	14/11/2025
4	Municipality of Eindhoven	12/11/2025
5	Municipality of Den Haag	08/12/2025
6	Province of Noord-Holland	18/11/2025
7	Province of Utrecht	10/11/2025
8	Province of Noord-Brabant	13/11/2025
9	Mobility hub developer A	13/11/2025
10	Mobility hub developer B	14/11/2025
11	Ministery I&W	02/12/2025

4.2. Mobility hub development within Amsterdam; state-of-the-art

The development of mobility hubs has become an important tool within mobility plans and strategies as has been analysed through literature. Within this light, exploratory interviews have been set up with municipal representatives to discover the different applications of mobility hubs within Amsterdam. Here, a focus was put on gaining insight on the development, functioning and evaluation of mobility hubs within Amsterdam. Through the interviews, different lessons were learned which are described and analysed within this research. The interviewees are anonymised within this research, but work in the municipal field of mobility hubs with different functions. These perspectives and insights are combined into an overall analysis where different quotes are highlighted.

Hub development within Amsterdam

The development plan of hubs within Amsterdam is mostly stated within the Hubvisie (2021) which derives from the nota Autoluw (Low-Car Traffic Policy) document. This forms the base for hub development and from this document the municipality of Amsterdam has looked into how hubs and shared mobility can contribute to the efficient design and use of the space within the city. This relates to the policy program 'Amsterdam Maakt Ruimte (2023)' (Amsterdam Makes Space), where the goal is to make the city liveable and approachable. Climate change and CO_2 emissions is also an important matter but not the main principle for developing hubs. The focus thus lies on a lack of space and liveability. The reduction of for example cars taking up public space creates more space for greenery, cycling and meeting places. Here, shared mobility is not a goal on its own but an effort to create the desired city

> "Public space is not meant solely for parking cars, but for being able to meet each other."
> -R2

> "My main goal is to create a liveable city and to use the space that we have more efficiently"
> -R1

Within the municipality, the typology of hubs follows from the Hubvisie where four different hubs are distinguished; neighbourhood hubs (buurthubs), city hubs (stadhubs), regional hubs (regiohubs) and districthubs (wijkhubs). The focus of the municipality mostly lays on neighbourhood hubs, which are smaller locations within the public space which often offers shared cars, bicycles and cargo bikes. These hubs are designed to organise the public space and to create less nuisance.

> "Nowadays I mostly categorise neighbourhood hubs, when can which hub be considered as what? That remains complicated." -R1

The intensity of mobility hub developments and its strategy have also shifted through the years from an "as many as possible" principle to targeted spatial integration on the basis of necessity and usage. Here, the municipality thus chooses to be selective rather than creating massive deployment of hubs everywhere within the city.

> "In the beginning, we wanted to develop an entire hub network with approximately 2200

> neighbourhood and district hubs, but along the way we started thinking; yes, but why? That is why we now look at how it can be spatially integrated." -R2

> "I am not going to cover the entire city with 400 hubs, that is a bit too much of a good thing." -R1

Through this targeted integration of hubs, development criteria are used to explore where hubs should be designed and developed. These criteria exist in threefold;

- Nuisance locations; locations where shared mobility gets in the way and is therefore seen as an hindrance. For example when shared scooters are scattered across the pavement. Here, hubs are used to restructure shared mobility and to cluster vehicles.

- Public transportation locations; places where public transportation is already offered and shared vehicles are connected to the travel chain. Here, shared mobility is used to travel the last-miles of travellers to their final destination.

- Destination locations; places where it is necessary to create more mobility options through hubs. Thus, these places are highly crowded since many people need to be there, places such as working areas or event venues.

> "We mostly look at places where the pressure on public space is high or the offer of shared mobility is very low." -R1

The municipality of Amsterdam sees hubs mostly as a location where shared mobility is offered, this excludes the consideration of other facilities mostly. Some developments consider the integration of functions such as lockers, but this is mostly seen as 'nice to have' rather than a principle. However, P+R (park and ride) locations are an example where the municipality sees ways to improve the liveability of the space towards a place where people feel more comfortable to wait. Demographically, it is considered which modes should be offered. Cargo bikes especially are not necessary at all locations, especially since they require a considerable amount of space. Therefore, different data such as usage per vehicle is monitored through providers on platforms to explore what user demands are applicable per region.

> "It is not the case that we have a blueprint for developing hubs, I do not think that that is going to happen, because every area asks for another developing approach. This thus depends on the know-how of our colleagues." -R2

Collaboration and communication
The development and functioning of hubs requires different collaborations with stakeholders. Collaborations are held with city districts (stadsdelen) for decision-making on public space, where meetings are held to explore which area needs a hub and why. For the standardisation of hubs, designers in the department 'Ruimte & Duurzaamheid' (space and sustainability) have created certain elements which a hub should contain, such as materials, signs, texts and references, but also on how a hub should be embedded within the area. For the technical implementation, engineering directors are employed to make feasible designs.

Beyond the design and development, a crucial collaboration is with providers of shared vehicles. Through permits, providers are allowed to offer their vehicles within hubs. Regular meetings are held to discuss the functioning of hubs. Furthermore, residents are seen as stakeholders within development before they are considered as users. Amsterdam values participation and residents included in design and development phases through their demand and needs.

> "Amsterdam values participation, thus this is included in the design of a hub." -R2

After the realisation of hubs, users are also important stakeholders for mobility hubs. The municipal representatives share that there is still much potential to gain for the perspectives of residents towards shared mobility and hubs. In order to change travel behaviour, awareness on the different applications of hubs is an important factor. In order to raise awareness, the municipality sets up campaigns such as 'Blij dat ik deel' (Happy that I'm sharing), where more visibility is created on the concept of shared mobility by displaying shared vehicles on the street with promotional actions. Moreover, neighbourhood meetings are organised to teach the concept to residents. The municipality explains that awareness

and an actual shift in mobility behaviour can only be reached by showing people the benefits. Further, one of the interviewees shares that the rise of actual user numbers is not the main goal, but it is of course beneficial if more people actually shift towards shared mobility. Here it is aimed to create a cultural shift from ownership to usage for residents in their mobility behaviour. During the campaign Blij dat ik deel, one of the interviewees also shared that many people are not even aware of the concept or the goal of the shared vehicles.

> "That we were standing with a cargo bike and bicycle in the neighbourhood which people could use. Then we started hearing people say; 'Oh, I did not know that Amsterdam had these'. And I get that." -R2

> "The best thing would be if we could give Amsterdam residents that "Aha-moment" : suddenly they see hubs everywhere." -R2

> "I continue to believe: it should be face-to-face advertisement and more vehicles on the street." -R2

> "From the moment that we can show what it offers, a change in behaviour develops." -R1

Monitoring and evaluation
The usage of mobility hubs in Amsterdam is monitored through different platforms, which make sure that insight can be gained on the performance of mobility hubs. Firstly, the CROW is a knowledge institute that collects data for municipalities and delivers this through providers by a CROW dashboard. This concept also functions for other cities and municipalities and delivers once per quarter insights on shared mobility within the region. However, this is not specifically an analysis per hub but this is a part of the general analysis. Furthermore, other municipal dashboards also monitor the usage frequency per vehicle, the spread of vehicles and parking sports. One of the interviewees mentions that it would be beneficial to have a minimum amount of vehicles offered per location at all times. However, this is rather hard to accomplish and for now, it is only a gentleman's agreement whether the provider actually commits to this objective. Another reference for the performance of hubs follows from the nuisance reports regarding shared mobility and mobility hubs. This involves the number of complaints that are received on for example scooters that are on the street. In this case, together with the provider, the service areas can be adjusted or new hubs could be realised.

As for evaluation, the interviewees express that this is a continuous process and not an end goal. Here, it is explained that evaluation is a part of everyday work and that evaluation should not be done for example each four years, but that continuous critical reflection is key. Moreover, the municipality states that it is rather hard to actually explore the effects of mobility hubs rather than general mobility changes and data. One of the interviewees states that indicators could be user growth per location, but that the actual effect on for example car ownership or trips is rather hard to establish and that is too early for the concept.

> "You should constantly reflect critically. We are really eager to learn, we still have a lot to learn." -R1

> "It is too soon to connect firm indicators, it is too unknown for people." -R2

> "We are now in the phase where we explore the impact of a hub when you develop one, does it perform the way we expected it would. " -R2

> "It does not solely revolve around data, it is also about the reality within the city." -R1

Since Amsterdam is not the only city that has developed mobility hubs, the municipality learns from other cities within the Netherlands and Europe. Especially from the G5, which are the 5 biggest cities within the Netherlands, lessons can be learned. One of the interviewees explains that standardisation and uniformity could enhance the functioning of mobility hubs. When uniformity in policy and execution is reached, easier adoption could be created for providers and users.

> "We do not have to invent the wheel 350 times." -R1

Challenges and opportunities

Since shared mobility has been introduced, the market has become more mature according to one of the interviewees. They explain that shared mobility has been integrated better into the mobility pattern of the city. Here, smaller providers have disappeared and larger providers mainly dominate the market. Shared scooters for example, have a higher acceptance rate throughout the city and are used more often in travel behaviours. One of the shared modes that still has high potential for urban mobility is the shared bicycle, however this is a politically fragile concept. Due to a history of a high rise of bicycles within the city, the promotion of shared bicycles is rather scarce. However, the potential remains high since bicycles promote active mobility and take less space than shared scooters. Therefore, shared bicycles could potentially be a key element for urban mobility.

> "The shared scooter is now a part of the city. The potential of the bicycle is high, it is an essential mode of transportation." -R1

One of the identified challenges from the interviewees is the level of awareness of shared mobility by residents. There is obscurity on the potential of shared mobility, as has been explained previously, which makes sure that more people could potentially be reached to start using shared mobility. However, the municipality representatives express that there is a low level of urgency with residents to use shared mobility. Residents do not always experience the potential effects of shared mobility within the city. Also, comfort is an important factor for residents' mobility behaviour. Moreover, one of the interviewees elaborates that a change of attitude towards shared mobility is rather difficult to accomplish since people tend to feel tense towards using shared vehicles. This is mostly due to the idea that the application of shared vehicles could be complicated. This is especially the case for low-literate or digital illiterate people, since the applications are online. Another inclusivity challenge is to make the services accessible for low income residents, since the usage of shared mobility tends to be relatively expensive.

Since the applications of shared vehicles are online, MaaS is an important concept to enhance integration of services. However, the movement towards this integration is considered as technically complex by the municipal representatives. Therefore, the challenge lies in how to develop such an integrated digital service.

> "The use of a shared vehicle is considered complicated by people. It is not yours which makes it scary." -R2

With these challenges, different future opportunities are also evident for the development and functioning of mobility hubs for the municipality of Amsterdam. Firstly, as just mentioned, the development of integrated MaaS application apps could enhance the user ease of existing and potential users. Another user opportunity mentioned within the interviews is to create inclusive shared mobility through an experiment for minimum wage earners with a city pass. Here, the municipality has set up a pilot to explore this opportunity. Thus, there are opportunities for creating better user experiences and user inclusivity.

Beyond the user perspectives, different systems and collaborations could also enhance the development and usage of mobility hubs. Firstly, the municipal representatives share that a regional sharing system could be implemented within the Vervoerregio (Transport region) Amsterdam. Currently, Amsterdam uses permits for regional usage of shared mobility. However, the goal is to move towards regional concessions within the Vervoerregio Amsterdam. This would result in better cross border usage and offers room for minimal availability requirements.

> "There are movements from permits to concessions on regional scale. This would be more efficient and better for the customer." -R1

> "We need to make services available citywide, otherwise you reduce its potential." -R2

Furthermore, collaborations with the G5 (the 5 biggest cities within the Netherlands) and the G40 (network of larger municipalities) could use knowledge sharing. By doing so, lessons can be learned from other areas where mobility hubs can be implemented. This could result in the standardisation and uniformation that was mentioned previously. Overall, more collaboration could create long term learning and effective decision-making in the development and functioning of hubs. Another collaboration could be with the NS (National Railway of the Netherlands) where the opportunity could be explored for

parking shared bicycles. Ideally, an interviewee shares that shared bicycles should be placed indoors (such as in NS parking facilities) to save public space. Overall, creating strong collaborations could form the base for effective development.

Finally, the municipality shares that attention will be raised for creating social safety and liveability for larger hubs such as P+R locations. Conditions could be enhanced to make sure that people have a better attitude towards waiting in such areas.

"It should not feel like a place where you do not want to be." -R1

Overall, the municipality thus shares challenges and opportunities in the field of mobility hubs. An overview of these considerations can be found in figure 4.1 where an overview is made with a SWOT analysis. The SWOT-analysis is used to map the strong and weak points of a project, as well as the potential opportunities and threats (Gürel, 2017). According to Leigh (2009), a SWOT-analysis is a method to make strategic choices by identifying internal and external factors that have an influence on the success of projects and plans. Therefore, the SWOT analysis given in Figure 4.1 can provide insights on which challenges are identified and how to seize opportunities for the mobility hub development.

The SWOT-analysis as visualised in Figure 4.1 offers an overview of these elements that can be considered within the mobility hub development in Amsterdam. This analysis is based on the insights that were gained during the interviews. Some mentioned strong points were the higher acceptance level and better integration of shared vehicles in the city. These strengths show the progress that has already been made within the developments. Further, some weaknesses were also revealed in the interviews such as low awareness of the benefits of shared mobility, the perceived complexity as well as the actual technical complexity of using mobility hubs which complicate user adoption. Also, it was mentioned in the interview with respondent 2 that realising a change of attitude is rather difficult to accomplish.

Opportunities for further developments are for example the integration of MaaS applications, creating more inclusivity, a better user experience and expansion of regional systems and collaborations. At the same time, threats are that there is political fragility and that there is a high dependence on external providers. Consequently, these opportunities and threats can be considered by the municipality of Amsterdam in future developments.

STRENGTHS

Higher acceptance of shared vehicles
Integration in mobility patterns

WEAKNESSES

Low awareness among residents
Change of attitude is complex
Technical complexity
Digital accessibility

OPPORTUNITIES

Integrated MaaS applications
Increasing inclusiveness
Increasing user experience
Further collaboration with other regions
Regional sharing system

THREATS

Politically fragile
Dependency on shared vehicle providers

Figure 4.1: SWOT analysis mobility hub development Amsterdam

4.3. Mobility hub exploration across the Netherlands

In order to gain insight on the potential for mobility hubs in Amsterdam, different regions have been explored. Here, different provincial and municipal representatives in the field of mobility hubs have been interviewed through in-depth expert interviews. The findings of these interviews are presented in this section, where per finding it is mentioned in which interview this information was collected. Firstly, a few highlights on the developments across the Netherlands will be highlighted. Then, a further analysis will be conducted on how different regions monitor and evaluate realised mobility hubs. With these new gained insights, lessons can be learned on how mobility hubs can be monitored and evaluated

effectively. By bringing together theory and practice, by combining the policy framework and the data from the interviews, an evaluation framework is set up.

4.3.1. Dutch mobility hub developments and role of stakeholders

Across the Netherlands, different stakeholders are involved in the development of mobility hubs. These stakeholders all have different roles and responsibilities when developing hubs within their region. Moreover, when developing mobility hubs, different strategies exist across these stakeholders. Therefore, the following section will elaborate which different roles exist as well as which different strategies as has become evident from the in-depth interviews. These insights can be useful to make appropriate recommendations for stakeholders when evaluating their hub developments, in terms of their tasks and responsibilities as well as according to their strategies.

Roles of stakeholders

Within the development of mobility hubs across the Netherlands, several roles can be distinguished by the interviewed stakeholders. Here, it was shown that provinces mainly take a coordinating and supporting role within the development. They stimulate the development of mobility hubs within policy frameworks, create research and facilitate knowledge sharing and help by co-financing development projects. Moreover, provinces tended to have a rather wait-and-see approach, where they intervene when no other party takes initiative at locations with high regional importance. For example, the province of Utrecht[7] explained that municipalities mostly do not take initiative for creating so-called corridor hubs which function as convenient entrances to cities. Then, the province takes on the role to initiate such a hub in order to seize the opportunities here.

Municipalities generally play a more central and operational role in the hub development. Municipalities translate policy ambitions in concrete hub developments within their municipality. Therefore, they are often responsible for the planning and implementation of hubs as well as monitoring and optimising hubs where possible. The municipality of Eindhoven[4] explained that they are mostly actively responsible for realising smaller neighbourhood hubs within Eindhoven, which is incorporated in municipal development plans. Overall, the municipal stakeholders were the most actively involved in taking initiative for hub development within their municipality, especially for smaller scale hubs. This reveals that municipalities are mostly responsible for performing evaluation since they are actively involved in developing mobility hubs as a mean for their municipal visions. Especially for smaller hubs in urban contexts, municipalities can be considered as the responsible actors.

Furthermore, two developers were interviewed who take on the role of designing and integrating hubs within concrete development plans. Here, the developers embed mobility hubs within area development plans as a tool to improve spatial quality, address parking pressure and to enhance accessibility and liveability. Developer B[10] explained to have a more pro-active role in actively integrating mobility in sustainable area development, by structurally collaborating with stakeholders to enhance concepts such as mobility hubs in area development.

Finally, one interviewee of the Ministry of Infrastructure and Water Management[11] (I&W) explained that the Rijksoverheid (national government) co-finances the development of hubs with terms and conditions. One of these conditions is that municipalities and provinces participate in knowledge sharing and research. Here, they facilitate the possibility for bringing together knowledge. Here, municipalities and provinces are responsible for the actual rollout of hubs. Furthermore the ministry is currently working on a national evaluation of mobility hubs. This will be elaborated later on in the report.

Hub development strategies

Not only do different responsibilities and roles exist across the different stakeholders, also different hub development strategies are carried out. As has been mentioned, most provinces develop hubs in high potential areas when municipalities do not take initiative. However, municipalities mostly have more specific development plans for hubs within their municipal plans. Here, there is a differing approach present among the different municipalities and the focus of this research is put on the development strategy for smaller scale neighbourhood hubs. The municipality of Amsterdam[2] explained to have shifted their approach from a 'as many as possible' approach to an approach where usefulness and necessity is seen as a principle for developing a hub. Furthermore, the municipality of Rotterdam[3] had a similar approach, where they first wanted to develop a large number of hubs within the city. Now, after

realising many hubs, the approach has shifted to exploring which areas are in need of the development of a hub. The municipality of Rotterdam can be considered a frontrunner with a total hub development of approximately 160 hubs by the end of 2025.

Some municipalities choose an approach where hubs are developed more as a network within a city. For example the municipality of Eindhoven[4] has developed a framework which states that every 300 meters should have one hub. Here, a GIS-analysis is used to determine logical locations for these hubs, where other aspects such as points of interest are also considered. Furthermore, the approach also states that when a certain point of interest or destination location is present, the hub should be within 100 metres of that point. The rate of development within Eindhoven is that there are 50 hubs realised and 30 to 40 more are in design.

Finally, the municipality of The Hague[5] has had a similar approach where they decided to realise 200 hubs, especially in the city centre and Scheveningen. Here, they explore with shared mobility providers what should be suitable locations. The first approach was to create a network of neighbourhood hubs where you are only able to park within the hubs. However, this turned out to be quite intensive to realise this network, so they shifted their approach to the one used in Rotterdam.

4.3.2. Available monitoring methods

In order to get a perspective on how mobility hubs perform after realisation, different monitoring methods are used. However, some stakeholders explain that monitoring is rather hard since hubs are still mostly in development such as within the municipality of Eindhoven. Moreover, shared mobility is thus hard to monitor due to it mostly being at the beginning stage. However, through different national efforts, more insights can be gained on how shared mobility and mobility hubs perform after being realised. Most of these monitoring methods focus on the user numbers of hubs, some focus on recognizing a change in mobility behaviour. These methods will be explained and examples will be given from different municipalities or provinces as of how they were mentioned within the interviews.

CROW dashboard

The CROW institute, as mentioned in Section 4.2, has developed a digital dashboard from which municipalities receive data on the usage of shared mobility. This dashboard is called dashboard Deelmobiliteit (shared mobility), in this research this dashboard will be referred to as the CROW dashboard. Within this dashboard, the capacity of different areas can be monitored in real time through data provided by shared vehicle providers (Kennisplatform CROW, n.d.). This can also be specified for specific hubs, where the capacity of the hubs is shown as well as how many vehicles are occupied. This allows to establish to what extent shared mobility is used within different cities, regions or areas. Municipalities have shared within the interviews that the CROW dashboard provides them insights on how many vehicles are used per hub, but also whether the capacity is right for each hub. Furthermore, insights can be gained on for example the down time of vehicles per hub. Overall, this information gives municipalities insight on whether hubs are performing according to their expectations.
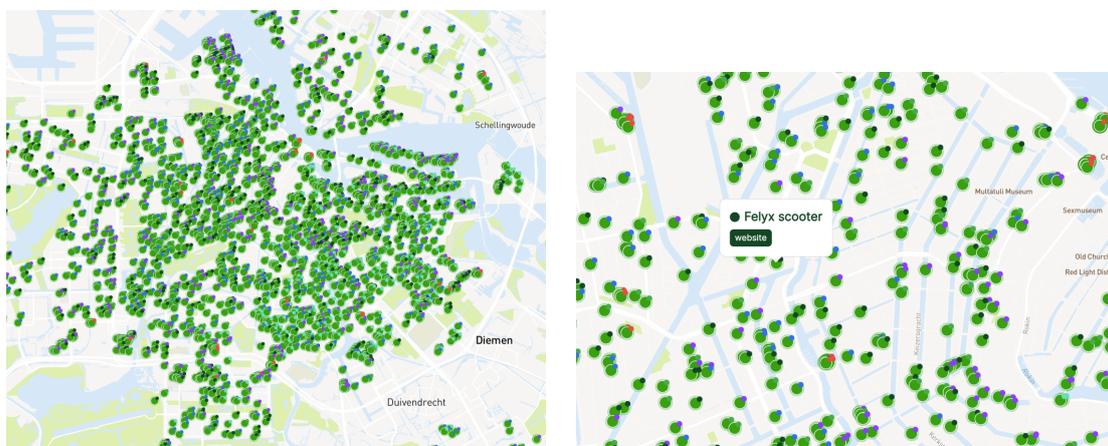

Figure 4.2: CROW dashboard (Kennisplatform CROW, n.d.)

For example, the municipality of Eindhoven[4] explains that these numbers can give feedback on whether hubs are too small or too large for how much they are used. The representative of Eindhoven explains that the dashboard could for example show that 14 vehicles are parked in a hub that has capacity for only 10. This could then be used to explore whether hubs should be enlarged or hubs should be added to the area. Moreover, this dashboard is also used within Amsterdam and could give valuable insights. However, the municipalities also share, as was also mentioned in the interview with the municipality of Eindhoven, that the dashboard has some flaws and that more monitoring through other monitoring efforts is favourable.
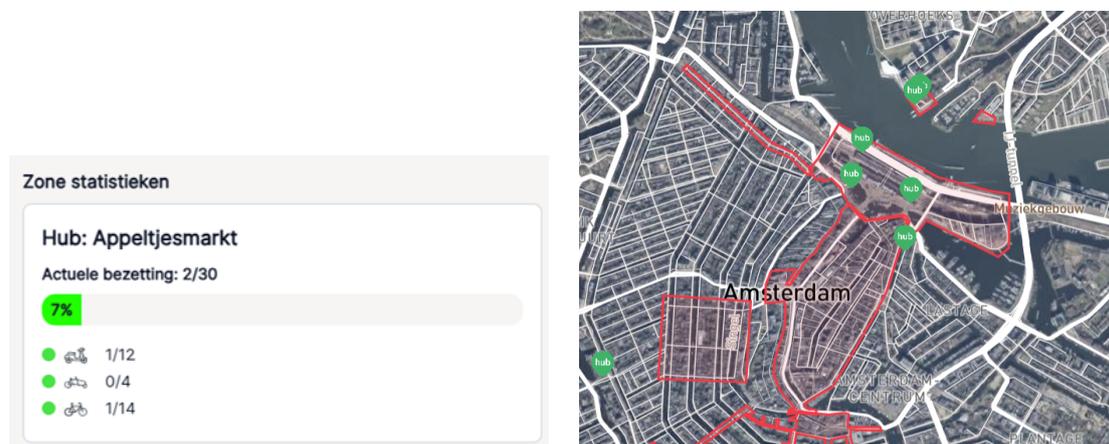

Figure 4.3: Hub statistics and hubs on the map (Kennisplatform CROW, n.d.)

Other municipal dashboards

Municipalities use other dashboards besides the one provided by the CROW. For example, the municipality of Rotterdam[3]m uses their own Power BI-dashboard which offers in depth analyses of hubs. This can be used to explore different patterns and trends of mobility hubs, as to display the performance of different hubs. Here, the municipality of Rotterdam explained that different elements within the dashboard are indicators for the performance of a hub. These elements are for example the occupancy rate: how many vehicles are at a hub on average in relation to the number of available spaces. The dashboard also monitors the usage of vehicles through the amount of rides, but also the downtime of each vehicle. Here, the representative of the municipality of Rotterdam explains the effectiveness of the hub as a relation of high user frequencies with a combination of low downtime, so whether the hub has a continuous throughput of vehicles.

Questionnaires among users

Other than the use of shared mobility within a hub and to monitor user numbers, it is also beneficial to explore mobility transitions and user experiences. Questionnaires are used to explore different aspects of travel behaviour. For example, the province of Utrecht[7] uses questionnaires to explore the start, destination and frequency of travels. This effort is an important source to understand which users use hubs and why they are using them. In this light, it can be explored whether hubs target the right travel groups. In regard to the previously discussed STOMP principle, hubs are mostly aimed to attract users that would otherwise use a car. It is not the goal to attract people who would otherwise make their trip by walking or cycling. However, the interviewees explain that not much research is performed on the actual motivations and changes in mobility behaviour. The mentioned surveys are performed on a small scale and could be further enhanced to make meaningful insights on modal shifts due to mobility hubs.

Public transportation numbers

Not only are the numbers of shared mobility monitored, also the public transportation numbers can give insights on the performance of hubs. For example, the province of Noord-Brabant[8] uses the number of new entrants and exits at public transportation hubs as an indicator for hub usage. These numbers are provided by public transportation operators, where a good collaboration is required. The representative

explains that they find it rather hard to monitor shared mobility usage and that public transportation could also be seen as a way to explore whether hubs are visited.

Modal split numbers
Besides the potential rise in public transportation numbers at hub locations, also the modal split numbers are used to predict the influence of hubs on the modal split numbers. Hereby, municipalities such as Amsterdam[1] and Eindhoven[4] explain that they have city wide yearly monitoring on the modal split. Here, it is also monitored which share shared mobility has within the number of total trips. By monitoring the numbers of shared mobility before hub developments and after hub developments, potential insights can be gained whether the implementation has led to a higher shared mobility number and maybe even lower private car trip numbers.

Quality appreciation of hub locations
Especially developers addressing monitoring the quality of developed hub locations. Hereby, the interviewees have explained that together with the CROW, satisfaction among residents on hub amenities are monitored. This monitoring consists of hubs and built parking amenities and it is explored whether projects with hubs are well sold and whether they are appreciated. Therefore, sale and rental data is used as an indirect indicator for monitoring the appreciation hubs. Also the province of Noord-Brabant[8] states that the quality of transferring points are monitored on physical aspects such as shelter, lighting and waiting areas.

4.3.3. Evaluation principles and current procedures
In order to explore how different stakeholders evaluate mobility hubs, interviewees were asked on what different municipalities and provinces see as crucial components in evaluation. Furthermore, the ministry of I&W is currently setting up a national evaluation process regarding mobility hubs across the Netherlands.

Mobility hub evaluation principles
Most interviewees state that there is currently limited evaluation on the functioning and impact of mobility hubs. Most of the evaluation that is available focuses on the numbers of users of mobility hubs. Nevertheless, it was explored within the interviews what elements the potential future mobility hub evaluation should contain. Several evaluation aspects that are considered important by interviewees are discussed in Table 4.2.

Table 4.2: Overview of mentioned evaluation principles for mobility hubs

Goal	Explanation	Explanation by
Nuisance reduction of parked shared vehicles	Reducing nuisance of shared vehicles is a rather hard KPI (Key Performance Indicator) due to its subjectivity.	Municipality of Eindhoven
Behavioural change in the travel chain	Realising a shift in mobility decisions according to the STOMP principles. Attention is paid to avoiding cannibalisation, for instance from shared transportation to hubs.	Municipality of Amsterdam
Motivation behind behavioural change	Not only is a shift in travel behaviour mentioned, but also the motivations behind these changes. This can show whether this leads, for example, to less car dependency.	Province of Noord-Brabant
Transportation guarantee	A minimum occupancy rate is used as an evaluation principle for hub performance. It was suggested that a vehicle should be available 90% of the time when demanded.	Municipality of Eindhoven
Quality requirements of hubs	Besides the offer of shared vehicles, quality requirements of the hubs are mentioned. It is evaluated whether residents and users recognise a hub, and find it accessible and easy to use.	Municipality of Den Haag
Evaluation on development level	Whether financial considerations and project progress are in line with expectations for project success. Finally, it is assessed whether quality is added to the environment and whether dwellings can be sold when no hub is provided but one is nearby.	Developer A

At the municipality of Rotterdam[3], the interviewee shares that biannual evaluation is performed in which the performance of hubs is assessed. Here, it is explained that hubs are evaluated on their performance from a user perspective. Overall, it can be noted from the interview results that evaluation mostly consists of monitoring usage data. Thus, evaluation mainly focuses on whether shared vehicles are used, rather than on an impact analysis. Hereby, municipalities and provinces indicate that, in many cases,it is simply too early to perform a broader evaluation and that insufficient guidelines have been established to do so.

National ongoing evaluation process

The interview with the representative of ministry of I&W[11] revealed the current progress of an ongoing national evaluation process. The national evaluation process for mobility hubs, on smaller scale shared mobility hubs level, has been an ongoing process since 2020. The reason behind this evaluation is to make the effect of hubs more tangible. As has been explained within the interview with the representative of the ministry of I&W, hubs are often considered to have success conditions but that there is currently little information available on the actual effectiveness and recurring patterns. Therefore, the process focuses on data collection and monitoring to gain insight on hub usage patterns, perceived effectiveness and influencing success factors.

As previously mentioned, data is collected across different municipalities using the CROW dashboard and through knowledge sharing. This data is crucial for understanding location-specific performance, usage trends and the impact of external factors like urbanisation, proximity to public transportation and seasonal variations. For example, a noticeable trend is that hubs near public transportation locations perform better than those in residential neighbourhoods. The goal is to standardize data collection, particularly for shared mobility hubs, and create a clearer picture of how hubs function across different areas.

As for now, the evaluation uses case development, where initial analysis focuses on understanding what can be considered an average hub. Going forward, the evaluation will further distinguish environmental aspects in location such as housing developments or transportation nodes, thus the analysis will be more context-specific. Within the evaluation process, different challenges are identified by the interviewee. For example, practical challenges such as incomplete data sets, fluctuating participation levels and differing environmental contexts lead to data gaps.

Within the current process, the ministry has moved towards recognising variation in local conditions. This means that efforts are focused on improving data quality and adapting evaluation aspects to reflect these contextual differences. The end goal of the evaluation is to inform future decisions aimed at improving the effectiveness and scalability of hubs. Where the focus is not only on usage but also on broader roles such as supporting sustainable transportation networks and providing integrated mobility solutions.

4.4. Conclusion

Chapter 4 contributes to this research by providing empirical insights to the theoretical and policy framework which was set up in the previous chapter. In this chapter, expert interviews with municipalities, provinces and developers are used to gain new knowledge on mobility hub developments, monitoring and evaluation. Therefore, this chapter bridges abstract policy ambitions to practical developments and monitoring. By combining these findings to the theoretical and policy findings of Chapter 3, input is formed for actually operationalising the effectiveness of mobility hubs in an assessable evaluation.

One key finding of this chapter is that the current evaluation practices are considerably limited, where evaluation mostly focusses on monitoring usage numbers. Within these current practices, little attention is given to societal impact and achievement of policy objectives. This is mostly explained due to the experience that limited data is available and that the impact is currently rather hard to measure. Interviewees emphasise that additional research is required for effective evaluation, where evaluation principles are translated into assessment.

Furthermore, this chapter highlights that effectiveness can be explained from two different perspectives, from a functional usage performance and from a societal impact performance. Various evaluation principles are mentioned where this distinction becomes evident, some aspects focus on how the hub functions and other focus on what is achieved by developing hubs. The interviews support this distinction, where effectiveness was considered through different perspectives. This division illustrates that evaluation can be performed on operational aspects as well as on policy dimensions. Additionally, the interviews show that goals and ambitions tend to be similar and overlapping at times. Not only did the empirical research explore the current practices, it also aimed to explore guiding principles for future evaluation. This resulted in that interviewees elaborated on what principles are considered in effectiveness of mobility hub developments and how this should be evaluated. These findings are used to further deepen and add components to the objectives identified in Chapter 3.

Overall, this chapter contributes to answering RQ2: *In what way do municipalities and provinces assess the performance of realised mobility hubs?*. The interview findings show that current practices mostly involve monitoring usage of mobility hubs. Furthermore, it is emphasised that stakeholders are aiming to evolve evaluation in a way that societal impact could be assessed. What is missing in this chapter is a structured translation of these gained insights into a coherent and applicable evaluation framework. Even though it illustrates which elements are considered as important, it is not established how these principles are operationalised and combined into one evaluation framework. Therefore, the next step of this research is to develop a translation of the theoretical and policy framework of Chapter 3 combined with the empirical findings of Chapter 4 into a structured evaluation method. The next chapter will focus on this translation into measurable assessment indicators, where an evaluation process is realised. This framework will be created in Chapter 5, aimed at assessing effectiveness of mobility hubs in a structured and coherent way.

5

Framework development

In order to explore the potential for evaluation in practice, the results of the literature study and interviews are combined into an evaluation framework. This framework will be used to evaluate the performance of realised urban mobility hubs. Firstly, this chapter will discuss the purpose of performing evaluation after realising developments. Then, effectiveness of mobility hubs will be established, to form a perspective from which points of view effectiveness can be perceived. Afterwards, the evaluation criteria will be operationalised where indicators are linked to goals regarding mobility hub development. These evaluation criteria are then combined within the evaluation framework. Finally, this chapter will explain how the evaluation framework can be put into practice.

5.1. Purpose of evaluation

Chapter 1 already introduced the report of Arnold et al. (2023) on the the 4P framework in mobility hub development where the fourth P stands for Performance. Hereby, Arnold et al. (2023) explain the importance of evaluation to determine whether the intervention of mobility hubs has reached the goals. The importance of evaluation here derives from the ability to improve future design resiliently and to identify unwanted results (Arnold et al., 2023). Finally, their research shows that ridership numbers are of high importance to compare effectiveness after implementation and that qualitative research is important to address questions such as experience and awareness of hubs.

The role of ex-post evaluation is discussed in the report of Dijk, Givoni, and Diederiks (2018) where it is stated that in order to effectively achieve change in travel behaviour, policies need to be considered through evaluation. Here, it is considered that the knowledge which can be gained through ex-post evaluations is a crucial component in the policy cycle to contribute to policy learning (Dijk et al., 2018). However, ex-post evaluation combined with ex-ante evaluation is infrequently performed and policies are frequently copied which leads to shortcomings (Dijk et al., 2018). Thus, the importance of evaluation is highlighted in policy and decision-making, where valuable lessons can be learned for future improvement. This would result in creating policy learning and developing more resilient and effective developments in the future.

5.2. Effectiveness of mobility hubs

Within the interviews, questions were asked regarding the effectiveness of mobility hubs to governmental representatives and developers. Here, different aspects were mentioned when defining the effectiveness of a hub. Moreover, a distinction in hub effectiveness became evident within these interviews which can be considered from two different aspects. Firstly, a primary goal of a hub is to enhance the use of shared mobility. This goal can thus be regarded as a way to increase the use of shared mobility as well as to improve the use of shared vehicles. Furthermore, this view of effectiveness is considered within this analysis as the effectiveness from the usage perspective.

However, the goal of creating a hub goes beyond improving and use of the effort of shared vehicles within cities. As has become evident from the policy review, different end goals have been defined

when setting up a mobility hub within urban areas. Therefore, the effectiveness of hubs can also be considered from a policy perspective. Here, the effectiveness is defined in terms of how a mobility hub contributes to achieve societal goals such as for example low car traffic areas. From the expert interviews and the policy review, these two different effectiveness perspectives will be considered before operationalising an evaluation framework for hub effectiveness.

5.2.1. Effectiveness from a usage perspective

As has become evident within the interviews, in order to enhance the usage of shared mobility within mobility hubs, different aspects play an important role. This role is seen as an enabling role for potential users to start or increase their use of shared vehicles within hubs. These different enabling factors are shown within Figure 5.1, where it is explained how each factor influences shared mobility.
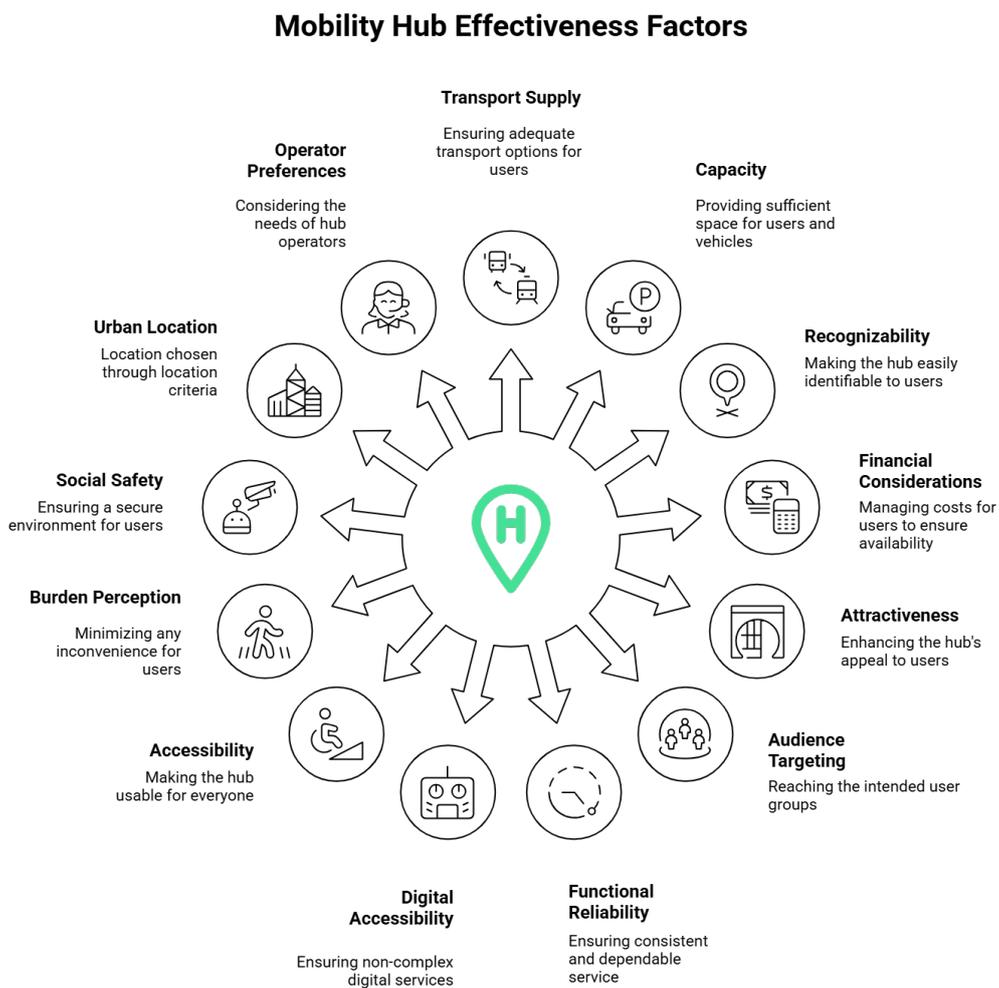
Figure 5.1: Factors for hub effectiveness from an usage perspective (images provided by Napkin AI)

These enabling factors need to be considered within the different phases of hub development. Furthermore, these factors are important in different phases of hub development. For example when designing a hub within an area, some factors focus on the physical aspects of a hub design. Nevertheless, other factors might focus on the operations behind the hub. Physical factors mentioned are, for example, the recognizability, the accessibility and the attractiveness of the hub. In addition, the operational aspects of a hub, such as functional operation and the appropriate transport supply of vehicles within the hub, are more ongoing processes. Therefore, the enabling factors of a hub are distinguished be-

tween two phases, the preparation phase and the operational phase. The preparation phase focuses on the design and the implementation of a hub and is an ending process. On the other hand, the operational phase is an ongoing process which involves forms of feedback and adjustments while operations continue.

For this research, these factors for the usage perspective will not be incorporated in the evaluation framework for mobility hubs, since the knowledge gap focuses on the societal impact of mobility hubs and the level of contribution to policy objectives. Therefore, the aspects for policy effectiveness will be used within the evaluation framework. The usage effectiveness can be used for responsible actors in hub development to enhance the use of shared mobility. Since the use of shared mobility hubs is the starting point of a hub performance, these lessons can be valuable for future hub development. Nevertheless, the evaluation framework will focus on the societal impact of mobility hubs rather than the use of them.

5.2.2. Effectiveness from a policy perspective

For the effectiveness from a policy perspective, dimensions of effectiveness have been created following from the policy review. Additionally, new dimensions or more specific dimensions have been created through the policy views of the expert interviews. One key finding from the interviews was that mobility hubs are designed to reduce nuisance, which was not yet identified in the policy review. These dimensions are roughly ranked in terms of how many times they have been mentioned within the interviews. This ranking was formed by using the tool ATLAS.ti, which allowed coding of recurring theme words in the interviews. These recurring themes have been linked to the different dimensions of hub effectiveness and show how hub development could potentially contribute to societal goals. Thus, through evaluating these dimensions, it can be explored whether hub development lives up to its expectations and potential from a policy framework. The figure below shows the different dimensions of mobility hub effectiveness from a policy perspective. The next section will operationalise these dimensions into evaluation criteria.

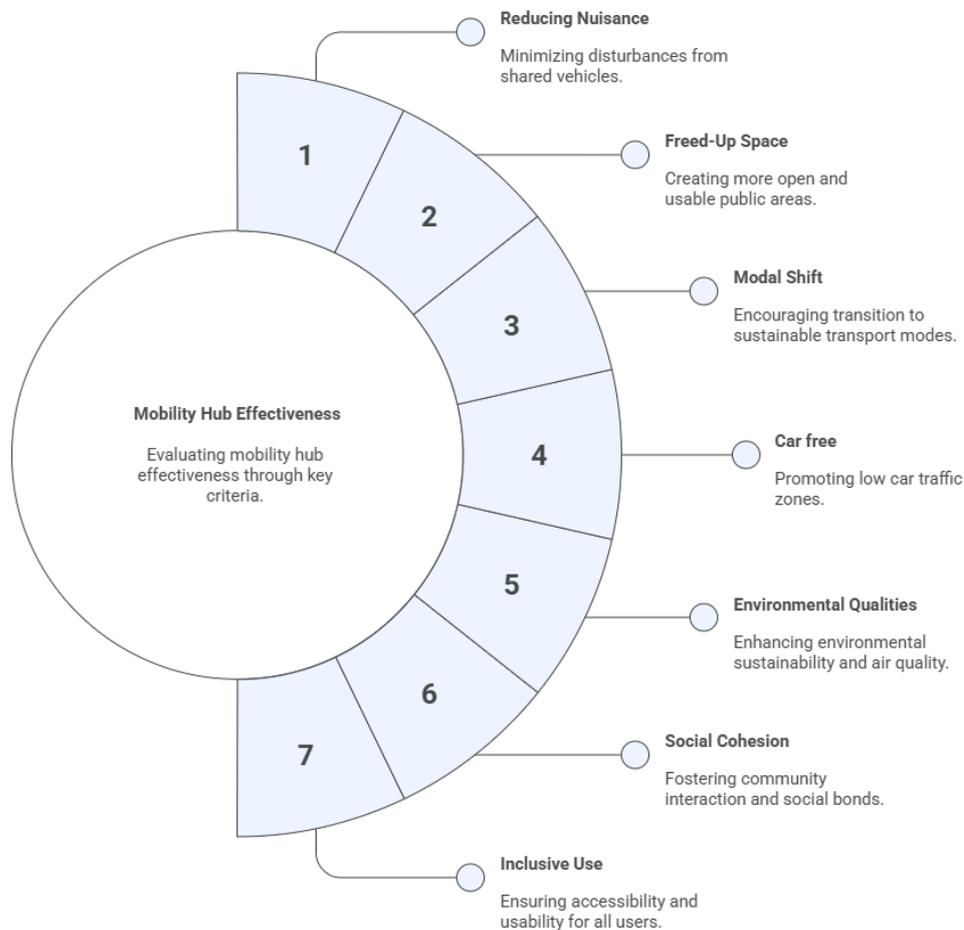**Unveiling the Dimensions of Mobility Hub Effectiveness**

Reducing Nuisance

Minimizing disturbances from
shared vehicles.

Freed-Up Space

Creating more open and
usable public areas.

Modal Shift

Encouraging transition to
sustainable transport modes.

Car free

Promoting low car traffic
zones.

Environmental Qualities

Enhancing environmental
sustainability and air quality.

Social Cohesion

Fostering community
interaction and social bonds.

Inclusive Use

Ensuring accessibility and
usability for all users.

Mobility Hub Effectiveness

Evaluating mobility hub
effectiveness through key
criteria.

Figure 5.2: Factors for hub effectiveness from a policy perspective

5.3. Operationalisation evaluation criteria

For operationalising the evaluation criteria, the effectiveness will thus be determined through the policy perspective. Here, the findings from the policy review will be combined with the results from the expert interviews. Firstly, the following themes for evaluation criteria resulted from the policy review; sustainable accessibility, spatial quality and inclusive cohesion. Moreover, the policy review showed different expectations and ambitions for developing hubs within urban areas. By combining the previous section of hub effectiveness with the themes which derived from the policy review, an evaluation framework can be formed.

In order to perform an ex-post evaluation on the performance of mobility hubs, different evaluation criteria are set up through the dimensions of the policy review. These evaluation criteria are operationalised by creating measurable indicators for the perceived achievement of each criteria. Here, a distinction is made in indicators, in terms of timely measurability. The indicators are distinguished into direct measurable effects, mid term environmental change and long term impact. By using this distinction, the evaluation can be used in different time dimensions after the implementation of a hub. Moreover, some goals and ambitions can not be measured in a short period of time due to it involving structural

changes in behaviour or perception which can happen gradually. Below, these three time dimensions are explained:

- Direct result: what changes can potentially be influenced by the implementation of mobility hubs? Here the focus thus lies on noticeable and measurable changes within the environment of a realised mobility hub. These indicators can potentially be explored within the case application of this research. These results are measured no more than one year after the realisation of a mobility hub.

- Environmental change: how does the mobility hub contribute to its neighbourhood and city? Within this time dimension, qualitative indicators are explored to see how a mobility hub might impact a neighbourhood or area. Further, these indicators are mostly measured in perception and qualitative features rather than quantitative indicators. Therefore, in order to explore this dimension, further qualitative research is required. These changes are measured between 1 to 5 years after the realisation of a mobility hub.

- Long term impact: to what extent does the hub lead to broader policy goals? This time dimension is rather hard to create measurable and tangible indicators for, due to it being broader concepts. These long term impact indicators will not be further analysed within this research. Long term impact indicators could be for example; increased liveability of neighbourhoods, space-efficient urban mobility networks and a structural shift towards resilient sustainable mobility.

Further, some indicators are interrelated and tend to be similar. For example, when someone chooses to take a shared vehicle instead of using their own private car, this contributes to a modal shift but also to a low car traffic environment. Therefore, indicators have been labelled into three different impact categories; spatial quality, sustainable accessibility and inclusive cohesion and are then linked to their overarching goals. These impact categories illustrate to what societal aspects each indicator would have an impact on. Within these categories, spatial quality shows how mobility hubs could enhance the quality experience of public space and how this is organised. Sustainable accessibility refers to maintaining or enhancing mobility, while moving towards more sustainable transportation methods from less sustainable modes. Inclusive cohesion refers to how mobility hubs could address inclusivity in mobility by providing more opportunities for different demographic groups, as well as to promote social cohesion within the hub development.

Additionally, some indicators have multiple overarching goals, since some goals have corresponding indicators for measuring their existence. However, this does not mean that these goals are the same. As has been explained, less people taking rides with their private cars contributes to less car traffic as well as to a modal shift. However, if someone chooses to go by bike instead of by scooter, this does contribute to a modal shift but not to lower car traffic. Therefore, these goals tend to be similar but are distinguished since they are not entirely the same in meaning.

Table 5.1 shows the list of impact indicators for direct results, meaning that they can be measured within one year after the hub development. Direct results does not refer to whether these changes are directly caused by the implementation of the hub. Thus, it should be noted that direct results refer to their measurability instead of their causality. Furthermore, this list of indicators merely consists of quantitative indicators, no qualitative indicators are incorporated.

Table 5.1: List of quantitative impact indicators

Category	Indicator	Overarching goal
Spatial quality[1,2,3,4,5,9,10,11]	Decline in illegal/nuisance parking of vehicles *# of reported vehicles*	Reducing nuisance
Spatial quality[1,2,3,4,5,9,10,11]	Decline in hindrance experienced by vehicles on the street *# of reported complaints*	Reducing nuisance
Spatial quality[2,3,4,6,8,9,10,11]	Removal of parking spaces m^2 *of removed parking space*	Freed-up space
Spatial quality[2,3,4,5,6,8,9,10,11]	Increased usable public space m^2 *extra space for public space*	Freed-up space
Spatial quality[1,2,3,4,5,6,8,9,10,11]	Reallocation of space within hub development m^2 *space reallocated due to hub realisation*	Freed-up space
Spatial quality[1,2,6,9,10]	Green added to surrounding areas cm^2 *extra green added to hub surroundings*	Freed-up space Environmental qualities
Spatial quality[1,4,6,9,10]	Expansion of pedestrian or cycling areas around the hub m^2 *pedestrian or cycling lanes added to hub surroundings*	Modal shift
Spatial quality[3,9]	Improved traffic noise levels in the surrounding area after hub development *Reduction in noise levels before and after hub realisation*	Reducing nuisance Environmental qualities
Sustainable accessibility[1,3,4,5,6,7,8,10]	Shift from car usage to shared mobility *% of users switching from car to shared mobility*	Modal shift Car-free Environmental qualities
Sustainable accessibility[1,3,4,5,6,7,8,10,11]	Shift from car usage to public transportation *% of users switching from car to public transportation*	Modal shift Car-free Environmental qualities
Sustainable accessibility[1, 3, 4, 5, 7, 8, 11]	Increase in shared mobility trips *% more shared mobility trips*	Modal shift
Sustainable accessibility[1,4,5,7,8,11]	Increase in public transportation trips *% more public transportation trips*	Modal shift
Sustainable accessibility[3,4,7,8,10,11]	Reduction in individual car usage *# trips before and after comparison*	Modal shift Car-free Environmental qualities
Sustainable accessibility[3,4,7,8,10,11]	Reduction in traffic volume in the area of the hub *volume decrease compared to baseline*	Car-free Environmental qualities
Sustainable accessibility[3,4,9,10,11]	Decrease in parking demand at nearby locations *#parking transaction in area*	Freed-up space Car-free Modal shift Environmental qualities

Sustainable accessibility[1,4,6,10,11]	Reduction in air pollution *% less NOx, CO2 emissions before and after*	Environmental qualities Modal shift
Inclusive cohesion[2,3,4,6,8,9,10]	Increased public space use around the hub % of people monitored at hub location	Social cohesion
Inclusive cohesion[2,4,6]	User diversity in income *Range of incomes of users*	Inclusive use
Inclusive cohesion[4,6]	User diversity in age groups Range of ages of users	Inclusive use
Inclusive cohesion[2,6]	User diversity in different demographics (families, students, workers, etc.) *Range of demographic groups*	Inclusive use
Inclusive cohesion[2,3,4,5]	Public engagement and involvement in hub-related activities (community events, surveys) *# of people involved within activities*	Social cohesion Inclusive use
Inclusive cohesion[4,8,9]	Accessibility features (wheelchair access, information pillars, multilingual features) *# of features added*	Inclusive use

Environmental change
Beyond the direct results, the environmental changes can also be analysed. Hereby, environmental changes are considered within 1 to 5 years after hub developments. Then, it is considered what environmental changes can be evident after hub development. Within these environmental changes, perceptions, attitudes and valuations are considered. Thus, the environmental changes sketch an image of how the environment surrounding a hub is experienced after hub development and its potential changes. Also within this evaluation scope, the categories of spatial quality, sustainable accessibility and inclusive cohesion are also distinguished. In this research, no evaluation framework is set up for the environmental changes. Nevertheless, some elements which could potentially be explored through future qualitative research are explained. These elements have been mentioned within the interviews as guidelines for area development and the implementation of hubs within those plans.

Spatial quality

- More space for greenery, seating, cycling, walking[1,2,3,4,5,6,8,9,10,11]
- Better spatial quality and street design[1,2,3,4,5,6,8,9,10,11]
- Enhanced use of public space[1,2,3,4,5,6,8,9,10]
- Improved pedestrian and cycling experience[1,4,8,9,10]
- Higher quality of stay in public space[2,3,4,5,6,8,9,10]
- Reduced experienced nuisance within an area, such as noise, congestion, pollution, etc.[1,2,3,4,5,6,8,9,10,11]
- Improved street safety and comfort due to less cars on the street[3,4,7,8,10,11]

Sustainable accessibility

- Consciously changed travel behaviour patterns[1,3,4,5,6,7,8,10]
- Reduced experienced car dependency[3,4,7,8,10,11]
- Improved experienced accessibility[1,2,3,4,5,6,8,9,10,11]
- Improved environmental perception[1,4,6,10,11]
- Reduced transport poverty[1,3,4,5,6,7,8,10]
- Improvement in public transport connectivity and comfort[1,4,5,7,8,11]

Inclusive cohesion

- Stronger neighbourhood connections[4,5,6]
- Increased social safety and vibrancy[2,3,4,5,6]
- Hub perceived as part of familiar street design[2,3,4,5,6,9]
- Improved accessible mobility for vulnerable groups[2,4,5,8]
- More equal affordable access to mobility opportunities[4,5,6,7]
- Improved community inclusion through co-creation and public engagement[2,3,4,5]

In order to assess the environmental change, residential research should be conducted to see how communities view potential changes within their environment. Hereby, it can be explored whether changes are experienced consciously and whether choices are made actively. By addressing potential changes in for example travel behaviour or perceived quality of public space, more insight can be gained on the potential long term effects of area developments such as mobility hubs.

Long term impact
The literature review revealed that mobility hubs are rather new concepts and that limited evaluation is available. Due to it being mostly new developments, it is rather difficult to predict the long term impact of the developed hubs. Therefore, the long term impact of mobility hubs was not much discussed within the interviews. In the scope of this research, the long term impact of mobility hubs is thus not considered in operationalising effectiveness.

5.4. Evaluation process

The set up evaluation framework can thus be used to explore the impact of mobility hub developments on pre-set policy goals. The evaluation framework is set up in a way that it can be used by municipalities and provinces to assess their policy goals. In order to use the evaluation framework in an evaluation process, this section will explain what input is needed for the framework, what phases the evaluation process consists of and finally which aspects are important to consider.

5.4.1. What input is needed for the evaluation?

For this evaluation framework, the evaluating stakeholder is thus a municipality or a province and it is explained what input these stakeholders need for performing an evaluation. For this evaluation framework, only quantitative input is considered. Quantitative input requires collecting data from different data sets and monitoring reports. Some required input is listed below on how data can be used to evaluate different indicators.

- Report files on nuisance complaints need to be monitored to see whether a decline of complaints occurs after hub development.

- Collecting different features of existing infrastructure in the hub area before and after development, such as the amount of parking spaces, the m2 used for bicycle and pedestrian lanes and amount of public space.

- Mobility numbers of the selected area are also an important aspect for evaluation. Hereby, modal splits, demand of parking spaces and the number of trips with shared and public transportation are examples of quantitative mobility input.

- Inclusive user statistics need to be used to explore whether the hub can be used for different groups. Therefore, statistics on appropriate price range and user characteristics need to be gathered.

5.4.2. What phases does the evaluation process consist of?

For the actual evaluation process of the framework, different evaluation phases need to be considered. These phases are explained below when the hubs has not been developed yet:
Evaluation phases if the hub has not been developed yet

1. **Phase 1: Before implementation**
   Within the first phase, the base case before hub development needs to be analysed. By doing so, the current situation can be explored resulting in insight on statistics and spatial layout before the mobility hub is realised. For the spatial quality category this mostly involves an environmental analysis of how the area is designed and the situation of shared vehicles parked on the street. For the sustainable accessibility this mostly involves exploring mobility numbers such as the current modal split or the volume of different modes on the road. As for the inclusive cohesion, it can only be analysed how the public space within the development area is currently used.

2. **Phase 2: During hub development**
   During the implementation phase, different adjustments within the spatial redevelopment should be documented. By doing so, it can be explored what changes have been realised by developing a mobility hub at a specific location.

3. **Phase 3: Right after hub realisation**
   After the mobility hub has been fully developed, it is possible to analyse which direct spatial changes have been made. Thus, it can be explored how the design of the street and or public space has changed by developing a hub. Furthermore, phase 3 uses the documentations from phase 2 to see what changes have been realised with the development of the mobility hub.

4. **Phase 4: One year after realisation**
   After one year, the evaluation framework can fully be used to explore the impact of the mobility hub on the set goals. Especially behavioural shift can become evident after one year, where the then current situation can be compared to the base case. Within this phase, the spatial quality, sustainable accessibility and inclusive cohesion categories can all be analysed by using the evaluation framework.

Evaluation phases if the hub has already been developed

1. **Phase 1: Base case**
   If the hub had already been realised, it is rather difficult to perform an environmental analysis on how the area was designed before the hub development. Nevertheless, it can still be considered how the spatial quality changes over time due to a hub. Furthermore, it can still be explored whether the hub results in shifting mobility or social behaviour over time. Therefore, if the hub has already been realised, a base case can still be made to explore changes. This base case can take two forms; sketching the scenario from before the hub had been developed or if the hub has been used for a longer time to explore shifts over the past year.

2. **Phase 2: New case**
   Depending from which scenario has been chosen, phase 2 of the evaluation can be performed. If scenario one is used, where the old situation is sketched, the evaluation can take place one year after the sketched scenario. This thus dependents on whether the hub has been developed within one year or if it had already been developed earlier on. For the scenario where the current situation is used, the full evaluation can be performed after one year. Hereby, the same conditions and results apply as in phase 4.

5.4.3. What considerations are important within the process?
the following aspects are important to consider:

- Some aspects are hub specific, such as accessibility features or the reallocation of space due to a specific hub. Other aspects may involve a larger area of evaluation than the direct surroundings of a hub. For example, whether people shift from private car usage to shared mobility or a reduction in air pollution. These factors tend to be hard to extract for a smaller area and can therefore be considered within a municipality or province.

- The level of direct or indirect impact due to a specific hub development is rather unknown. Since mostly quantitative indicators have been set up, it is more complex to explore to what extent the development of a hub has a direct impact on for example a modal shift of residents. Therefore, no hard conclusion can be drawn whether a specific hub development results in a direct or full impact to an indicator. Meaning that only assumptions can be made on the potential effect of hub developments on policy goals while only using this quantitative framework.

- Municipalities or provinces can use different benchmarks for the indicators on whether they can be experienced as 'good'. For example, a smaller municipality might value a relative smaller impact of higher value than a larger municipality such as Amsterdam. This can be the result of the urgency of desired results, since Amsterdam might have more pressing parking issues than a smaller municipality. Therefore, the benchmarks for each indicator may differ when using the set up framework.

5.5. Generic evaluation framework

The framework that has been set up in Figure 5.3 is a proposed assessment to translate policy objectives into measurable indicators that evaluate the effectiveness of mobility hubs. This framework starts with a goal orientation where the effectiveness from a policy perspective is used, these objectives are illustrated in 5.2. Therefore, the starting point of the evaluation is to explore these objectives that are the product of different policy goals and ambitions. Hereby, different policy documents have been used to set up societal ambitions and objectives for developing mobility hubs. Also, the interviews with different governmental representatives added new objectives or deepening of explored policy documents.

The next step of the framework shows that these objectives can be quantified into measurable indicators. These indicators have been operationalised in Table 5.1 where indicators measure direct results within one year after hub realisation. Further, the indicators are categorised into the societal impact categories; spatial quality, sustainable accessibility and inclusive cohesion. In the proposed evaluation framework, the list of indicators in Table 5.1 is used for the quantification of goals.

In order to actually evaluate the societal impact of mobility hubs, data needs to be collected to measure the constructed indicators. Different data sets and monitoring reports need to be used to acquire the

needed data for the indicators. Examples of data sets and reports are mentioned in Section 5.4.1. This data collection requires data from different scales, where data varies from hub-specific information such as reallocation of space in development to broader scale data such as the modal split within the area.

When data has been collected, the evaluation step can be assessed where the different evaluation phases from Section 5.4.2 are followed. Since the data has been collected, it can be explored what changes have occurred and how each indicator is measured. For this evaluation, the considerations from Section 5.4.3 need to be taken into account. This means that the scale of measurement should be considered, to see whether the indicators on hub level or larger scale differ. In this light, the level of direct influence should be considered to see what contribution the hub potentially makes and what other external factors might be influential. Finally, the considerations show that evaluation of the indicators depends on the benchmarks that stakeholders might set for measuring the indicators.

By following these steps, a generic evaluation framework was set up. This means that this framework consists of all mentioned possible goals that might exist for mobility hubs. However, within this framework the different contextual aspects of hubs are not considered. Therefore, the framework now assumes that the each developed mobility hub can use this framework despite of hub aspects and specific policy objectives for that specific hub. However, as has been mentioned within 3.2.4, hubs have differing contextual aspects that influence their functioning and purpose. Therefore, the proposed framework is flexible in use for different stakeholders and different mobility hubs, but proposes a generic evaluation framework rather than targeted evaluation.
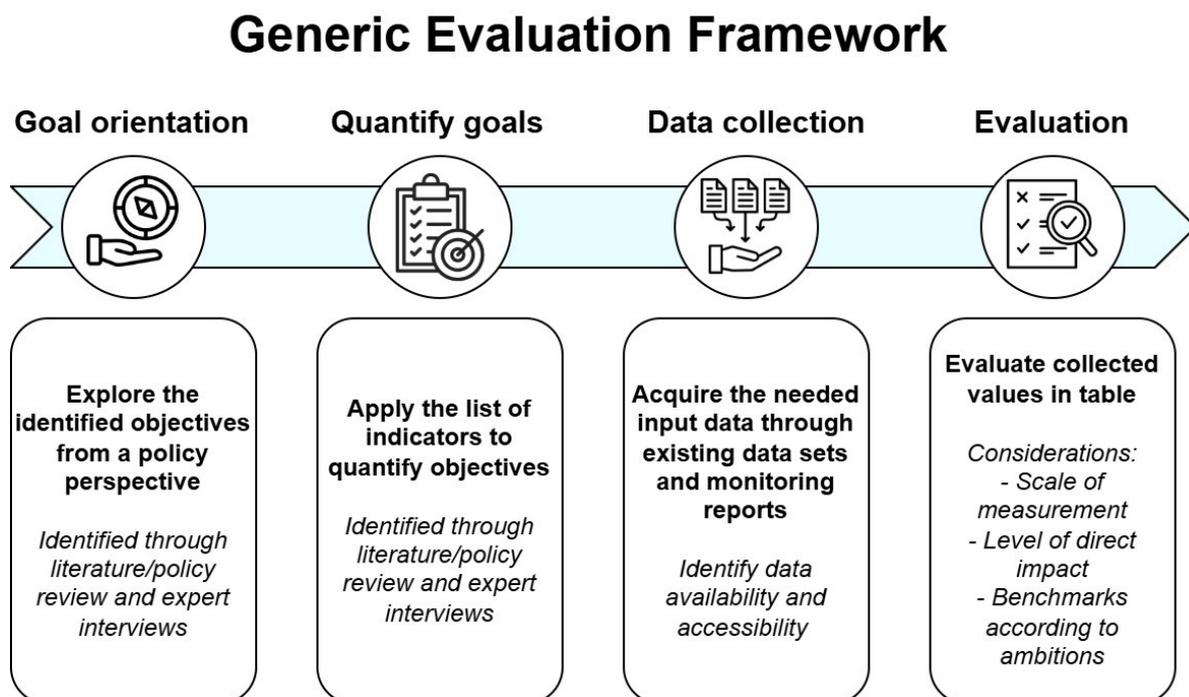

Figure 5.3: Generic evaluation framework

Now that this generic evaluation framework has been set up, an exploration can be made on how specific hub aspects and objectives influence the use of the framework. The following chapter will consist of a case application in which the framework will be assessed through a real example of a realised mobility hub. This allows the research to explore how the framework can be specified and adjusted to one specific context. By performing a case application, the different opportunities as well as the limitations of the framework and process can potentially be identified by practical exploration. In the end, this could illustrate how the framework can go from a one-size-fits-all framework to a framework that acknowledges context-dependency.

5.6. Conclusion

This chapter presents the development of an ex-post evaluation framework for realised mobility hubs, based on a combination of literature review, policy analysis and empirical insights from interviews. One key distinction shown in this chapter is that effectiveness can be described from a usage perspective or from a policy perspective. This distinction formed the basis of operationalising evaluation criteria, where the framework assesses effectiveness from a policy perspective that measures the societal impact. Effectiveness from a policy perspective is considered through the different objectives illustrated in 5.2 which serve as input for the evaluation framework.

Additionally, this chapter illustrated how this effectiveness from a policy perspective could be translated into measurable indicators. This translation resulted in a list of indicators in Table 5.1, where each indicator was mentioned during the interviews. These indicators illustrate how objectives from the policy analysis and empirical analysis can be translated into measurable indicators for assessment. After this operationalisation of direct result of mobility hubs on societal objectives, an evaluation process was set up. This process involved the data collection of input data for the indicators and the phases that evaluation should consist of. Finally, this chapter presented some considerations for this evaluation process on scale of indicators, level of direct impact and differing benchmarks. Consequently, all these steps are combined into a generic evaluation framework. This framework presents a method for assessing the societal impact of realised mobility hubs. The framework aims to give guidelines on how to evaluate formulated objectives into a measurable assessment. Overall, this chapter contributes to answering RQ3: *Which indicators can be applied to assess the desired effects of a realised mobility?*. This chapter illustrates how abstract policy ambitions and goals can be translated into an applicable set of indicators in an evaluation process. Hereby, Chapter 5 serves as an important methodological step for bridging policy objectives to a practical evaluation.

However, this chapter also presents some missing aspects in the current findings. First of all, the practical applicability of the proposed framework has not been tested. Therefore, it remains rather unclear to what extent the framework can applied to a real case. Furthermore, such a critical test of the application could also explore whether the constructed objectives and indicators align with specific hub characteristics, local policy prioritisations and availability of data sets. Even though the proposed generic framework acknowledges influence of context and scale, it is not specifically explored in a realistic application. Nevertheless, these missing insights will be addressed in Chapter 6, where the evaluation framework is applied to one case of a realised urban mobility hub located in Amsterdam. This chapter will test the applicability in terms of objectives, context and data. Further, it will identify possible challenges in usage and interpretation for evaluation. Chapter 6 serves as a critical test of the assumptions and choices that have been made in this chapter and aims to deepen and sharpen the proposed evaluation framework.

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Testing the framework in one case

In this chapter, an application of the framework to one case is performed to assess whether the developed evaluation framework can be put into practice. By performing this case application, it can be explored whether the evaluation framework contains elements that are not realistic to evaluate or whether certain components are missing. Also, it can provide challenges in context-dependency of hubs in evaluation. Therefore, a specific hub within Amsterdam has been selected to explore the functioning of the evaluation framework. Firstly, the selection criteria for this case will be presented as well as an analysis on the different hub aspects and the environmental context. After this analysis, hub monitoring is performed to explore the functioning of the mobility hub with the use of the CROW dashboard. Further, the evaluation framework is applied to the case, where practical considerations are made of the evaluation procedure. Through this analysis, it is explored which components could be adjusted for potential improvement of the framework, resulting in a deepening of the proposed framework in Figure 5.3. Finally, this chapter will conclude with the gained insights from the case application.

This case application does not focus on measuring the effectiveness of the hub, but rather on the applicability, completeness and feasibility of the proposed evaluation framework in a real policy context.

6.1. Aim of case application

Due to scarce direct access to quantitative data sets and the framework having quantitative indicators, the focus lies on feasibility of the created indicators within the framework and the evaluation process. Therefore, the applicability of the framework will be assessed on three different aspects: whether the indicators align with the physical and functional aspects of the selected hub, the relevance of established indicators in the objectives of the mobility hub and the practical feasibility of the data collection and evaluation process within municipal context. By analysing these aspects systematically, it can be argued whether the framework is theoretically feasible, regardless of the data availability within this research.

In order to perform this analysis, a case application on a selected hub in Amsterdam is performed. By actually using an existing case within the analysis, more insight can be gained on the applicability of using the framework on a specific developed mobility hub. Therefore, the selected mobility hub Appeltjesmarkt can function as a critical test location. By exploring the different aspects of hub Appeltjesmarkt, it can be suggested whether contextual aspects of a hub play a role in the applicability of the framework. Furthermore, the case application could possibly reveal which indicators are strongly dependent on external data sets beyond the municipal data sets. Additionally, it may reveal which indicators might need an additional qualitative approach to fully utilize the framework in practice.

6.2. Selected mobility hub analysis

Firstly, the selected hub in Amsterdam will be presented, where different aspects are highlighted. In order to make insights on the usability of the framework, the selected hub will be analysed on different aspects. It will first be explained why this particular hub is chosen for analysis. Then, it will be analysed

what different aspects this hub has in terms of functions and services. Also, a small environmental analysis of the hub will be presented to form a better understanding of the different influential factors surrounding the hub.

6.2.1. Selection criteria

For this application, the hub Appeltjesmarkt has been selected which is located at Elandsgracht in the city centre of Amsterdam. Before analysing this hub, it will be further explained why this specific hub is chosen for the case application.

- Firstly, Amsterdam was chosen as a municipality due to mobility hubs being integrated in mobility and spatial planning within the municipality. For example, the Hubvisie 2021 shows an example of how the municipality has laid out documents for conceptualising and implementing mobility hubs in urban area development. Due to this policy interest, Amsterdam has been chosen for a case application to see how different policy objectives can potentially be evaluated in regard to mobility hub development.

- For this case application, the decision has been made to explore one specific hub rather than multiple mobility hubs. Moreover, this decision has been made due to limited time within the research. Also, one hub is selected instead of multiple hubs since the case application functions as an exploration on the functioning of the set up framework, instead of actually evaluating the output that could be collected through the framework.

- The hub Appeltjesmarkt has specifically been chosen due to size and location. Since the hub is located in the city centre, it is placed in a crowded environment with many potential users. Due to the location within the city centre of Amsterdam, there is limited public space. Furthermore, the hub not only includes public transportation and shared mobility, there is also a parking garage located. Overall, hub Appeltjesmarkt can be considered as a larger scale neighbourhood hub located in an urban dense area. This hub has limited public space and a high functional offer within a city center area. Due to this combination, the hub could potentially attract many potential users due to it being close to points of interest and few parking possibilities within the city centre.

6.2.2. Hub aspects and environmental context

In order to explore the hub on aspects such as functions, size and location, an environmental analysis will be performed. Firstly it will be shown which different services are located within or nearby the hub and then the hub surroundings will be analysed. Hub Appeltjesmarkt has different mobility services which are listed below:

Located services

- Bus station Elandsgracht
- Tram station Elandsgracht
- Q Park Europarking parking garage (including electrical vehicle charging)
- Gas station
- Bicycle parking racks
- Shared mobility within hub location:
  - (electric) bicycles
  - (electric) cargo bikes
  - (electric) scooters

Figure 6.1: Mobility hub Appeltjesmarkt images (own pictures)

The image below shows the hub Appeltjesmarkt and its surrounding hubs within and close to the city centre. Here, the hub which is used in this case application can be found next to the red no-parking square on the map. As can be noted in this image, neighbourhood hubs have other hubs within the same areas. Therefore, it can be challenging to extract certain results for one specific hub when other hubs are located nearby.
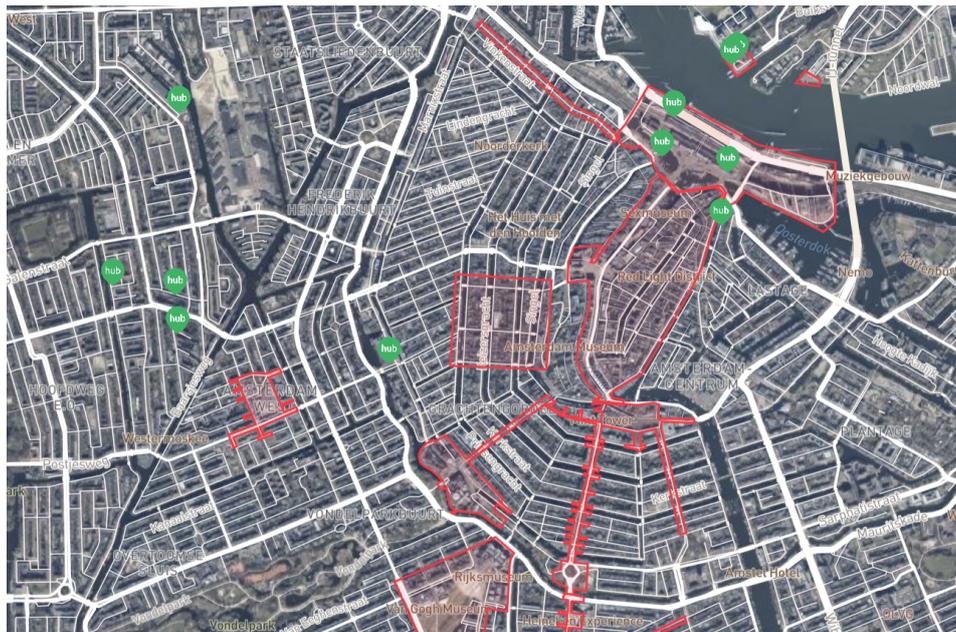

Figure 6.2: Selected hub and surrounding hubs (Kennisplatform CROW, n.d.)

Neighbourhood analysis
As for the area in which the hub is located, some environmental factors and demographics have been analysed through the environmental analysis performed by the municipality of Amsterdam in 2022. This analysis illustrates the different environmental aspects within the area and thus provides environmental context. The area in which the mobility hub is located is Amsterdam Center-West. However, it should be mentioned that the environmental analysis of the area was performed before the hub was developed and that some aspects might be influenced by the Covid-19 pandemic. Nevertheless, some insight can be gained on the different aspects of the area. Some highlights are listed below, all retrieved

from Gebiedsanalyse 2022 Centrum-West (Environmental Analysis 2022 Center-West) by Gemeente Amsterdam (2022).

- Center-West has the highest resident density in the city, which is mostly the result of visitors. The area is the busiest area of Amsterdam.
- The area has the lowest amount of greenery from all city areas. Residents are relatively poorly satisfied with the offer of greenery.
- The amount of car parking facilities is the lowest of all areas, the amount of bicycle parking is below average.
- Due to a lack of space and reparation of quay walls, the accessibility, parking, traffic density, through-flow and noise are under pressure within the area.
- The area of Center-West has the highest amount of nuisance, mostly due to hospitality facilities.
- The level of neighbourhood development under residents is under average.
- The residential social-economical score (SES) is above average. Furthermore, the social cohesion is on an average level but was under pressure in 2022.
- The area has a relatively low level of low-literate people, the average age of the area is getting older relatively fast.

Parking dynamics
Another aspect which is considered when developing hubs is reducing car dependency within the city centre. In this light, the parking pressure in the city centre of Amsterdam presents some challenges regarding car parking. For example, the parking tariffs per hour for parking on street within the hub area are 8 euros and 5 cent in 2026(Gemeente Amsterdam, n.d.). Further, the area of Elandsgracht has an average parking pressure of 90% on weekdays, meaning that parking demand is high within the area (Gemeente Amsterdam, n.d.). Finally, regarding parking permits, Amsterdam follows strict policies on allowing residents a parking permit. Within this policy, Amsterdam reduces the amount of parking permits for different areas on average two times per year (Gemeente Amsterdam, n.d.). Here, it is explained that by reducing the parking permits, less cars are parked in public spaces, allowing the opportunity to create more attractive public space. Thus it can be concluded that it can be considered difficult to rely on using a private car within the city centre. Therefore, the hub development could present opportunities to reduce the parking pressure by providing more mobility options.

6.3. Hub monitoring

As has been mentioned, the data availability within this research is scarce, which complicates assessing the performance of the evaluation framework. Nevertheless, in order to gain some insight on the effectiveness from an user perspective, a hub monitoring has been performed. By performing this monitoring, some statistics can be analysed and evaluated for the hub Appeltjesmarkt. Within this monitoring, the hub has been analysed in terms of quantitative aspects which have been monitored through the CROW dashboard. Through this monitoring, it can be explored to some extent, whether the hub is well developed by assessing the factors for an effective mobility hub.

Due to not having access to municipal data, this first monitoring will solely focus on performance indicators which are monitored through the CROW dashboard. Therefore, this monitoring does not result in specific insights on the societal impact of mobility hubs. However, it shows whether some of the factors mentioned for user effectiveness are reached. For this monitoring, the CROW dashboard has been monitored a couple of times per day for a week.

6.3.1. CROW dashboard monitoring

As mentioned, the CROW dashboard has been used within this research. Due to limited access to the functions of the CROW dashboard, not all usage numbers were available. Within the CROW dashboard, actual user numbers are restricted for people other than for example municipalities and shared vehicles providers. Nevertheless, some insights were gained when monitoring the dashboard. The images below shows examples of the data from the dashboard. Some insights from monitoring this data dashboard are:

- One of the functions of the dashboard is to see how many vehicles are parked within the hub. The image shows that during the monitoring, the capacity of shared bicycles for this specific hub was exceeded. Meaning that more shared bicycles were parked at the hub than the dashboard provides as capacity.

- By showing how many vehicles are parked at the hub, it also becomes evident how many vehicles are available for rental. As can be seen from the data dashboard, not all indicated vehicles were present at all times. For example, the image shows that no scooters and cargo bikes were available
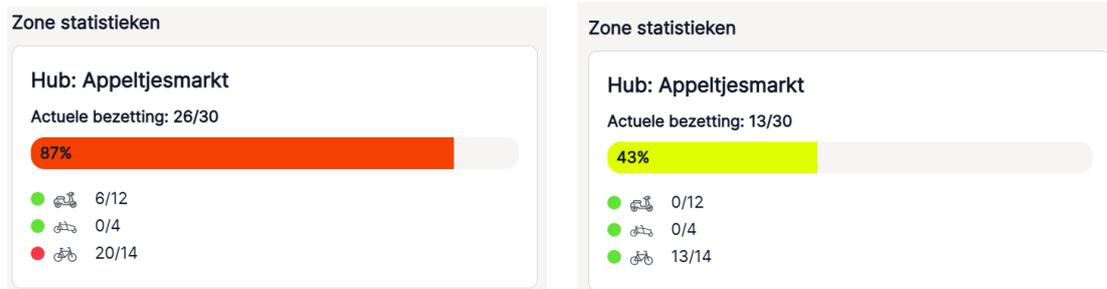
Figure 6.3: Data dashboard in CROW dashboard (Kennisplatform CROW, n.d.)

Besides from being able to see the capacity and the amount of available vehicles per hub, there are also other features in the CROW dashboard. For example, the dashboard shows where vehicles are parked on the map. The image below shows an example of the parked vehicles which are in the same area as the hub. From this image it can be noticed that vehicles are also parked on the street outside of the hub. Therefore, it is evident that even though the hub is located, vehicles can be and are still parked outside the geo-fence of the hub.
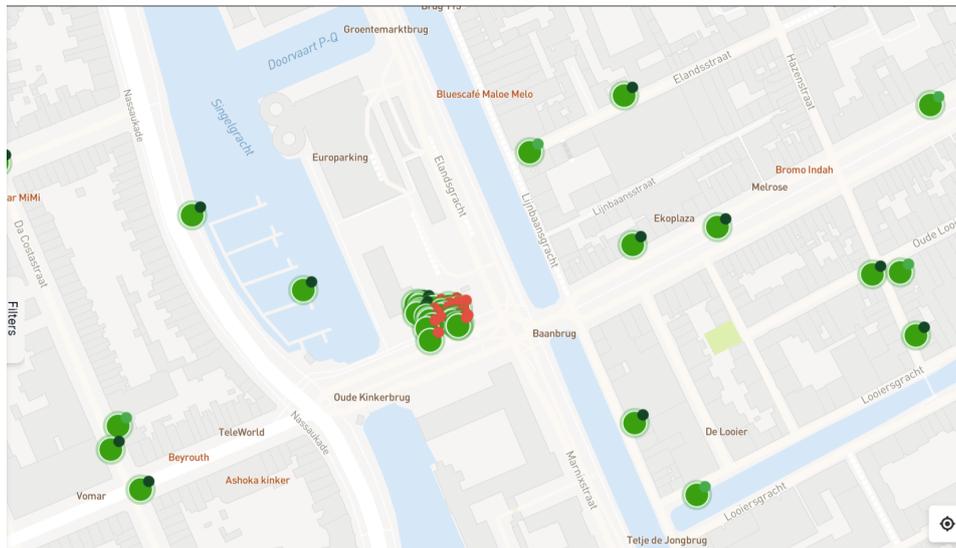
Figure 6.4: Parked vehicles on the CROW map (Kennisplatform CROW, n.d.)

As has been mentioned, due to limited access, it was not possible to monitor data on the actual use of the shared vehicles for the hub Appeltjesmarkt. Therefore, no statements are made on whether the hub performs well in terms of rentals.

6.4. Practical considerations evaluation procedure

In order to establish the practical feasibility and applicability of the framework for the hub Appeltjes-markt in Amsterdam, different elements are considered. Firstly, the application of the framework will be assessed on three criteria; whether the indicators align with the physical and functional aspects of the selected hub, the relevance of established indicators in the objective of the selected mobility hub and the practical feasibility of the data collection and evaluation process within municipal context. After this assessment, some considerations and remarks will be further explained.

6.4.1. Testing the application of the framework

Firstly, the three mentioned elements will be tested for this case application. This will possibly reveal strong points of the framework as well as limitations or sensitivity. For the first two aspects only the most notable findings will be analysed, the third aspect will assess the entire evaluation procedure.

Alignment of indicators with hub aspects
The indicators within the framework have been compared to the functions and environmental analysis of hub Appeltjesmarkt. The following notable findings are listed below:

- Indicators involving parking: as has been mentioned within the environmental analysis, the area has a high parking pressure. This means that many people experience not having enough parking space. Next to the hub there is a parking garage located, since this is a parking garage in a building it would be difficult to remove individual parking spots here. Also, since there is a high parking pressure, it is questionable whether parking spots would be removed by the addition of one mobility hub in this area.

- Indicators involving modal shift features: within the city centre of Amsterdam, it is rather hard to travel by car due to narrow streets and low parking availability. Therefore, trips by car into the city centre are already quite limited. Also, as mentioned, there are many points of interest in the city centre and therefore are public transportation networks frequently used. Thus, it might be rather hard to create a visible modal shift through this added mobility hub in the city centre.

- Indicators involving use of public space: since the hub is located within the city centre, many people pass this point. Therefore, it is questionable whether the addition of a hub would lead to more people using the public space, since the area already has many visitors.

- Indicators involving creating more space: due to narrow streets and limited space within the city centre, it might be hard to realise adjustments such as expansion of pedestrian or cycling lanes. However, additions of greenery and seating has a potential to be located here.

Relevance of indicators in hub objectives
Now that the alignment of the indicators with the hub aspects has been analysed, the relevance of the indicators on the hub objectives will be explored. The development of the mobility hub Appeltjesmarkt aligns with multiple important objectives that are established by the municipality of Amsterdam. One of this goals which corresponds closely to this particular hub is efficiently dealing with available public space. Since the city and especially the city centre tend to be crowded and dense urban areas, pressure on public space exists. In this context, the spatial quality within the framework forms an important guideline for the hub evaluation.

In this light, one important indicator within the city centre, mentioned in the interviews with respondent one and respondent two, is that shared vehicles need to be kept of the side walks as much as possible. Therefore, in order to organize these shared vehicles, mobility hubs could potentially create less nuisance. Subsequently, important indicators here are declining reported illegal/nuisance vehicles on the street as well as the decline of reported complaints concerning shared vehicles. By efficiently concentrating vehicles in hubs, efficient use of public space and a decline of considered nuisance can be achieved. This directly connects to the municipal ambition of enhancing the quality of public space within the city centre and thus at hub Appeltjesmarkt.

Additionally, by this reorganization of spatial quality, contributions can be made to social satisfaction and an improved spatial image. By well organizing and integration within the city area, the hub could potentially contribute to a more liveable environment. This might benefit the quality of public space and enhance social interactions.

Finally, the mobility hub could potentially offer a good alternative for traditional on street car parking, which would especially benefit the city centre. By enhancing the availability from shared vehicles, the private car dependency could potentially be reduced even further. In this way, the hub could contribute to policy goals for reducing cars in the city centre. Nevertheless, the hub could make sure that accessibility to points of interest stays on a high level. Within urban context, cars can be considered impractical and the addition of shared vehicles could offer a flexible alternative for last mile trips. This is in line with the municipal ambition of Amsterdam to promote mobility options that fit into the city's spatial constraints.

Practical feasibility evaluation process

1. *Input data collection*

   For collecting the needed data, the municipality of Amsterdam has various data sources. These different data sources are crucial for evaluating the performance of a mobility hub and in this case application particularly Appeltjesmarkt mobility hub. Moreover, the input data for the framework can mainly be collected via existing municipal systems, but also external collaborations are necessary. By communicating with external partners such as shared vehicle providers and the public transportation operators, more data can be gathered. Below, the indicators have been categorized into different themes for which the needed input data is considered. Firstly, it will be explained what data collection methods and data sets are required for each indicator theme. Then, the practical feasibility of collecting the input data will be discussed. This will then form an overview of what methods are needed as well as what the feasibility is.

   - **Street occupancy and parking behaviour**

     Firstly, the street occupancy and parking behaviour relates to the parking of shared vehicles and private cars on the street. The municipality of Amsterdam can obtain the private car data by analysing the amount of permits and parking transactions within the area of Center-West. As mentioned in 6.2.2 the parking permits and parking pressure of Center-West are already analysed through municipal systems. This parking pressure contains the statistics on parking transactions and in this way the private car parking behaviour can be explored.

     As for the parking behaviour of shared vehicles, it can be considered how many shared vehicles are wrongly or in a hindering way parked. For exploring the amount of hindrance, nuisance's reports can be monitored. However, not all of these incidents are actually reported. Therefore, it can also be explored with shared vehicle providers how many vehicles are parked outside of geo-fences of hubs. Also, through the shared vehicles providers, data can be gathered on whether too many vehicles are parked within a hub since this could also cause nuisance.

     – *Practical feasibility?*

       As stated, data on private car parking is already gathered by municipal systems and is therefore considered a relatively easy method. Also the nuisance complaints can already be collected by municipal customer platforms, as mentioned by respondent 2. Further, a collaboration with shared vehicles providers is required, for example through the CROW dashboard. This does not require a lot of effort since this data is already monitored digitally.

   - **Change in mobility behaviour**

     In order to explore the indicators that address modal shifts and less car traffic, different mobility numbers are required. As for the modal shift, the modal split numbers of Amsterdam can be compared to see whether a shift occurs. In reports such as Monitor Autoluw (Low car traffic) (Amsterdam, ODiN, OS, & CBS, 2023), numbers are mentioned for the modal split in Amsterdam. These numbers are monitored by the Dutch CBS which is a statistical institution. To gain more insight on which specific modal shift residents have made, additional surveys can be performed to see what mobility shifts have occurred.

     Also, the car dependency can be monitored and evaluated in Amsterdam. The municipality already collects information on different data of car ownership and rides. An example is the research on different traffic statistics which is called 'Verkeer in cijfers' (Traffic in numbers)

(Gemeente Amsterdam, 2024). Through this type of research, more insight can be gained on potentially changing mobility behaviour.

  – *Practical feasibility?*
  Since research is already performed on the mobility behaviour of Amsterdam's residents, it can be considered relatively easy to gather this data. Hereby, the mobility numbers are used for the entire city of Amsterdam. This might lead to many underlying motivations for changing behaviour. Therefore, surveys can be performed to see which shifts have occurred. User surveys are feasible, but require active involvement from municipal teams in order to achieve sufficient participation. Traffic measurements can be carried out relatively easily, as the municipality already has traffic sensors installed in the city.

• **Use of public space and social cohesion**
Also for the use of public space and social cohesion, input data needs to be acquired. As can be seen in the neighbourhood analysis, Center-West has many visitors and is a crowded area. Research is already performed on how many people thus use the public space in the area. Additional statistics can be monitored to see how many people use the area around the hub. This can be done by using sensors and observations. Furthermore, to capture the social cohesion, the municipality can explore video observations. Also, data on the diversity in users can be gathered by shared vehicle providers and potentially additional surveys.

  – *Practical feasibility?*
  Since the use of public space is already measured, this is a relatively easy aspect to monitor. Further, it can be explored how many people specifically use the hub area by performing additional monitoring. For obtaining information on the user diversity, detailed demographic statistics are required. This can be more challenging since it involves knowledge sharing with providers and potentially additional research through surveys.

• **Environmental impact and sustainability**
Air quality measurements can be carried out by existing municipal air monitoring stations, which already collect relevant data for the city. Hereby, it is not realistic to explore the change in pollution for one specific area around the hub. Furthermore, it is difficult to explore to what extent the hubs have a role in these changes without additional surveys. Thus the input data for the framework can be realised, but to gain more insight, more research is required.

  – *Practical feasibility?*
  Air quality measurements are relatively easy to carry out because the municipality already has air monitoring stations. However, the change in environmental behaviour is more difficult to measure without user surveys and requires active research.

Table 6.1 provides a clear overview of the necessary data collection, its current availability and how it can be used for the analysis. This table highlights the data needed for various indicators, the current status of data availability and the potential methods for acquiring missing data. Additionally, it specifies who can provide this data and how it might be used in the context of mobility hub evaluation.

Table 6.1: Input data collection for evaluation framework (Case application)

Indicator	Required Data	Current data availability	Missing data and potential data collection
Street occupancy and parking behaviour	Private car parking data (permits, occupancy rates, transactions), shared vehicle parking data, nuisance reports	High availability municipal parking systems and nuisance reports. Limited CROW dashboard access and providers' information	Structural data exchange with shared mobility providers. Monitoring of vehicles outside geo-fenced areas. Systematic before and after parking pressure analysis.
Change in mobility behaviour	Modal split data (percentage shift), shared mobility usage statistics, traffic intensity data, user surveys mobility behaviour	Partially available and often through external stakeholders(CBS, provider data)	Hub area modal shift data. User surveys shifted mobility behaviour. Improved access to shared vehicle parking data. Enhanced traffic sensor analysis around hub.
Use of public space and social cohesion	Public space usage statistics, demographic user data, observations of interactions	Partially available public space analysis, municipal reports, sensors and observations	Detailed user diversity data from providers. Structured perception quality of public space surveys. Additional hub-focused interaction observations.
Environmental impact and sustainability	Air quality data, traffic-related emission data, environmental perception surveys	Available at city level through municipal air monitoring stations, not hub-specific	Hub-level environmental measurements. Comparative before and after implementation data. Surveys linking behavioural change to sustainable mobility.

2. *Evaluation phases*
   For completing the evaluation phases, cooperation between stakeholders is crucial. The reflection of the data input revealed that collaborating with external parties such as shared vehicles providers or statistical institutions is very important. The data collection therefore depends partially on external parties and making sure that tight relationships are created. The municipality must ensure that effective data exchange can be achieved. Hereby, knowledge sharing can be reached through shared databases such as the CROW dashboards, regular update meetings and joint research initiatives such as by the Ministery of I&W. Clear agreements need to be established for analysing the data in a way that data certainty is reached.

   Furthermore, user data through surveys also serves as additional input in different travel patterns and behaviours. Here, an active attitude by the municipality is required to make meaningful insights on structural changes.

3. *Evaluation process considerations*
   As explained in 5.4.3, different considerations were mentioned within the evaluation process. Firstly, some evaluation aspects are hub specific and other aspects are broader area effects. Specific factors for hub Appeltjesmarkt can be for example accessibility features and the real-

located space after hub development. These specific aspects can be monitored directly by the responsible stakeholders in this specific hub development. For area related measurements such as parking behaviour, existing municipal systems can be used that explore area Center-West.

Nevertheless, some effects that are evaluated within the framework require broader data sets and perspectives such as the modal shift from private cars to shared mobility or air pollution reduction. This can mostly be evaluated on city scale by the municipality. Furthermore, the impact on structural change remains difficult to quantify without additional motivations and insight. Since the developed framework only uses quantitative indicators, no clear conclusions can be drawn on whether the hub's impact has a direct effectiveness on long term or city wide goals. However, assumptions can be made about the potential whether it could contribute to municipal goals.

As was just revealed, the indicators relevance depends on the specific objectives the municipality of Amsterdam has. In Amsterdam, with its pressing parking problems and lack of public space, larger changes in mobility behaviour and space use are likely to be seen as a success. Smaller municipalities, on the other hand, may value smaller and faster changes, such as a limited decrease in car use. This difference in benchmarks is related to the urgency of the desired results and the size of the city, which can lead to different measurable goals.

The evaluation of the Appeltjesmarkt hub must take into account both local and urban effects. Quantitative data such as parking occupancy and traffic pressure can be measured locally, while broader impacts such as modal shift and air pollution require a broader city focus. The municipality will evaluate based on benchmarks that align with Amsterdam's specific societal challenges, such as parking pressure and creating more public space. Combining quantitative and qualitative data has proven to be essential for an in-depth evaluation

6.4.2. Further deepening of framework application

In order to create a more complex and in-depth framework for future research, some reflections that have emerged during this research will be discussed in this section. These reflections address some considerations that could potentially further develop the framework. This is discussed to identify current limitations in the framework and to explore opportunities for improvement. First of all, the current framework does not consider the motivations that lead to the usage of a hub. Within section 5.2.2 the user effectiveness has been discussed, where different enabling aspects are mentioned for using a mobility hub. However, these enabling factors and the framework do not address underlying motivations of using hubs.

While a mobility hub could be designed according to spatial and technical standards, this does not automatically guarantee its use. Even when a mobility hub is considered as a 'perfect' design according to current knowledge of stakeholders, it can still fail to achieve objectives due to unwillingness to use it. Thus, this presents a knowledge gap in the current evaluation framework, which focuses solely on measurable outcomes. These measurable indicators provide some insight of what changes potentially occur but lack the ability to explain structural mobility choices and motivations.

The currently developed evaluation framework functions as a technical assessment where statistics and observable effects are measured. Hereby, it is thus not revealed which underlying attitudes and perspectives result in motivations behind user behaviour. This partially results in an additional knowledge gap on how observed changes are direct or indirect consequences of the development of a mobility hub. For example, when a reduction in car dependency and usage is observed, this may not be solely attributable to the hub implementation but could also be the result of other external factors. These external factors could for example be pricing of other transportation modes, policies and other societal trends. This creates a difficulty in establishing a direct causal relationship as was already mentioned in the evaluation framework considerations. Therefore, the proposed evaluation framework functions as an effort to explore the contribution of mobility hub on objectives measured on a regional or citywide scale rather than creating a tool that measures the direct influence. However, direct impact can be considered for indicators that are measured on a mobility hub scale, such as accessibility features and added greenery.

Another reflection which could be explored to further deepen evaluation efforts is whether the success

of a mobility hub should solely focus on reaching policy objectives. The way the framework is currently set up, effectiveness is linked to policy objectives. This raises an important question; if certain policy goals are not achieved due to a mobility hub, does this then indicate hub ineffectiveness? On the other hand, the question would then be whether a hub alone would not be able to achieve objectives but that it could serve as a supporting development. If the hub is considered ineffective for reaching objectives on its own, should the hub then be adjusted or should the expectations be reconsidered from a strategic tool to a supporting tool. This tendency highlights the need for evidence-informed decisions in mobility strategies regarding the use of mobility hubs.

To address these uncertainties, additional research is needed that focuses on user perceptions and preferences. Understanding which elements users consider essential for using a mobility hub could help bridge the gap between technical performance and actual use.

6.5. Gained insights of case application: adapted framework

This case application analysis has demonstrated how the proposed evaluation framework can be tested at a realised mobility hub in one specific urban context. Here, it was analysed that the framework can to some extent assess the performance of one urban mobility hub, when different considerations are followed in application. First of all, it became evident that the objectives for effectiveness from a policy perspective in Figure 5.2 are not all considered of high priority for the hub Appeltjesmarkt. Some objectives are considered important for this specific hub such as reducing nuisance, while others are of less priority. Therefore, the application reveals that it can be analysed which specific objectives a mobility hub has before performing an evaluation.

Further, the application also explored the context of hub Appeltjesmarkt by critically reflecting on the list of quantitative indicators provided in Table 5.1. This revealed that not all indicators for measuring effectiveness are relevant or even applicable. This consideration informs that not all indicators should be applied within the framework for all different hubs. In this light, it was already discussed that not all objectives are considered of high priority for each hub. Since the indicators are linked to objectives, if objectives would not be considered of importance, these specific indicators might also not be relevant to analyse. Thus, the list of indicators should be considered through a policy objective and context dependent perspective.

In this application, it is also argued that the practical applicability depends largely on the availability and accessibility of quantitative data sets. This input is essential for a proper assessment through the proposed evaluation framework. Within this case application, access to such data sets was very limited, therefore no firm conclusions can be drawn on whether the proposed input is the fitting data. Also, no fully practical application of the evaluation framework could be performed due to this missing data.

The case application of the Appeltjesmarkt mobility hub illustrated which specific data sets would mostly like be needed for fully applying the framework. Further, preconditions for accessibility to data sets also requires knowledge sharing and data collection of external stakeholders such as shared vehicle providers and data institutes like the CBS. Within this case application, this collaboration was assumed to be of relative easy nature due to existing collaboration. Without the data input, the framework fails to explore quantitative indicators and the impact on societal changes.

Besides from the necessity of data input, the framework also highlighted the need for additional qualitative input. Due to the quantitative nature of the framework, no assumptions can be made on underlying motivations and attitudes. Therefore, it can, for example, not be noted whether someone actively uses a different mode of transportation due to the hub realisation. Furthermore, since the indicators are measured on different scales, it is harder to draw firm conclusions for the causality for indicators measured on a larger scale than the hub itself. For example, the modal shift within an area is also influenced by other external factors. Thus, in order for the municipality to make explicit statements on the causal relation between hubs and objectives, additional information is needed.

Nevertheless, some indicators in the framework can indicate direct results from the mobility hub development. These indicators explain direct changes that can be measured on mobility hub level such as the spatial integration, accessibility features, availability of transportation modes and changes in public space. Moreover, these aspects can be analysed through observations, usage statistics and other mu-

nicipal data sets such as complaint reports of residents on shared vehicles. Overall, this difference in measuring causality and scale results in a dynamic evaluation procedure. In addition, the case application analysis highlights the value of a mixed methods approach, where qualitative indicators are added with the aim to explain certain motivations and drivers in behavioural changes in mobility. This could then also contribute to explore the causal relation between mobility hub developments and changes in mobility behaviour.

Finally, as has been mentioned in the following quote during the interviews:

> "I am all for evaluation; it is simply part of your daily work. It is not something you should evaluate after four years, but you should continuously take a critical look. For example, we started with the Hubvisie, but now we are already on a slightly different path. It is a matter of learning and we are very keen to learn from this, so we are certainly not done learning yet." -R1

Since evaluation should be considered as a continuos critical reflection, feedback can be obtained from each step which can be used for later adjustments in the assessment. By constantly learning from each different step, more policy learning can be achieved. Therefore, feedback is also considered in the framework, where each step informs future assessments. Overall, all these considerations after the application lead to the following adapted evaluation framework in Figure 6.5.
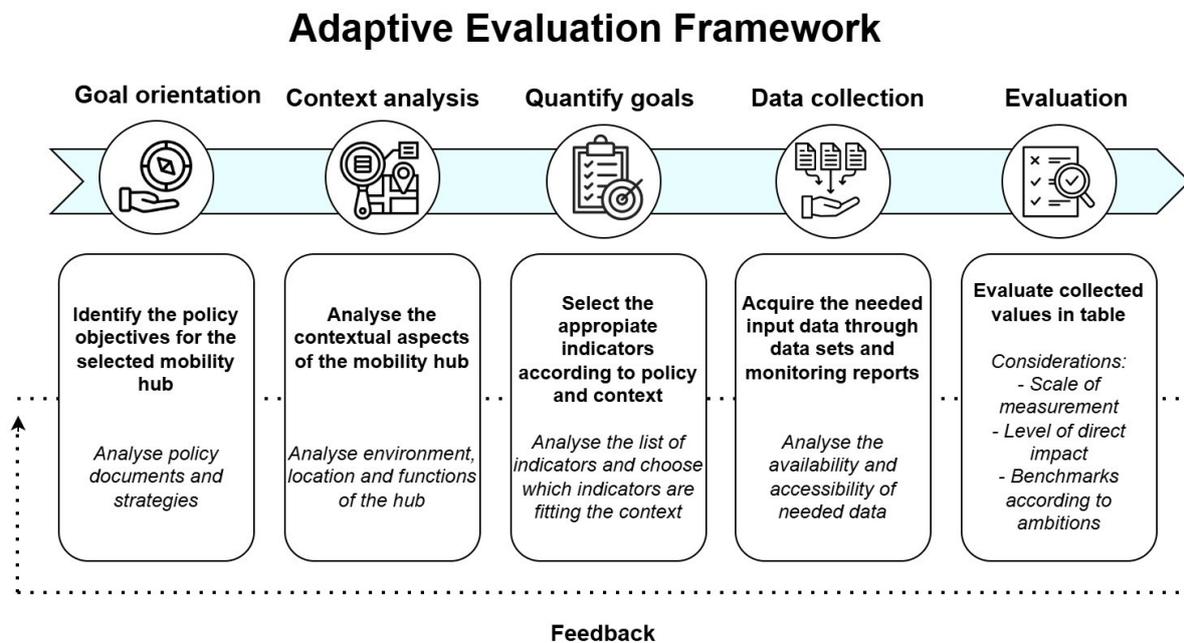
Adaptive Evaluation Framework

Figure 6.5: Adapted evaluation framework

Overall, this case application at hub Appeltjesmarkt served as a test location to explore application in one specific urban context where limited public space is available and high intensity of residents and visitors are present. This context highlighted the interpretation and application of the evaluation framework where certain aspects play an important role. Theoretically, the framework provides indicators that are applicable in a generic sense. However, in practice, indicators should be interpreted on environment, hub aspects and relevance of policy objectives. This implies that adaptive usage of the framework is critical instead of a rather static tool for evaluation. Thus, for each assessment, the framework is redefined and prioritized for each mobility hub context. Finally, the application of the research aimed to test the feasibility of application, due to limited data access, assumptions were made on whether data was easily accessible or not and what collaborations should be managed. By combining these gained insights from the case application, all these considerations are applied to the adapted framework. This resulted in the adapted framework in Figure 6.5, this framework acknowledges the policy and environmental context of a hub to be an important influence for applying an evaluation framework.

6.6. Conclusion

Chapter 6 translated the developed evaluation framework into a concrete application for the Appeltjes-markt mobility hub in Amsterdam. Rather than remaining conceptual, the framework was applied to a specific policy and spatial context in Amsterdam. By doing so, this chapter demonstrated how the proposed evaluation framework in Figure 5.3 from Chapter 5 can be applied in practice. This results in an application that takes local policy objectives, hub specific context and data availability into account for one specific urban mobility hub.

The findings show that the framework is applicable within the Amsterdam context in the scope of this research, as it aligns with existing policy goals such as reducing nuisance and enhancing public space. At the same time, the application highlights that evaluating mobility hubs is context-dependent. Certain indicators were revealed to have less relevance or applicability for the selected case. Therefore, it shows that objectives and indicators should be adapted to a specific context. Furthermore, this chapter highlights the necessity of availability and accessibility for required input data. This revealed that not all considered needed data is directly accessible for the municipality and that collaboration with other stakeholders is needed for additional data sharing.

In addition, this application showed how interpretation of measured indicators also depends on scale of indicators and their direct impact. As was discussed, indicators measured on hub level can be attributed more directly to the development of a hub than indicators measured on a larger scale. This requires interpretation within the broader urban dynamics of Center-West and the external factors influencing mobility behaviour. This underlines that the framework should not be seen as a definite measurement tool, but as a structured yet adaptable instrument that can be specified to local circumstances. In this light, additional research, potentially of qualitative nature could address the uncertainty in the directness of influence of a hub development on societal changes.

Overall, Chapter 6 directly addresses RQ4: *How can the effects of a selected mobility hub in Amsterdam be assessed through a developed evaluation framework?*. This chapter shows that assessment is possible by embedding the framework within municipal practices and by operationalising indicators in a way that reflects both policy ambitions and specific hub context. It demonstrates not only the potential technical feasibility, but also the practical relevance of the framework. The insights from this application provide a foundation for the discussion in Chapter 7. By revealing both the strengths and contextual limitations of the framework, Chapter 6 enables a critical reflection on its transferability to other hubs or municipalities and its value for policy evaluation and learning.

7

Discussion

This chapter will discuss the findings that have been formed within this research. Hereby, it will interpret the findings from the empirical research and link these findings to the theoretical background. This will provide a better understanding of how theoretical gaps and theories within mobility hub development and evaluation are addressed within the research through exploring different concepts. Further, the contribution to literature and policy practice will be discussed. Overall, this chapter will reveal the findings of this research that bridge the gap between theory and practice.

7.1. Interpretation of findings

This research aimed to explore how the effectiveness of realised urban mobility hubs can be assessed through an ex-post evaluation framework in relation to their intended policy goals. By combining a literature review, policy analysis, expert interviews and a case application, this research contributes to more insights on the implications of mobility hub development. By focusing on evaluation rather than design or implementation, this study addresses an important gap in both academic literature and policy practice. This discussion reflects on the findings within this research in relation to existing theoretical literature. The contribution of this research reflects on gaining key insights on effectiveness, evaluation and context-dependency.

Mobility hub developments as multifunctional and policy-driven interventions

The development of mobility hubs is increasingly used by municipalities as a tool to facilitate a transition towards a new transportation method. One of the key findings in literature is that mobility hubs are mostly considered as developments that have a societal impact rather than solely a mobility infrastructure. This framing was found in literature and policy documents where mobility hub developments aim at different policy goals to face societal challenges. Further, this aligns with literature on how mobility hubs are embedded within wider development processes. Studies showed that mobility hubs have different ambitions related to accessibility, sustainability, a modal shift and liveability. However, this research demonstrates that these ambitions are differently interpreted and prioritized across municipalities. Furthermore, it is revealed that policy ambitions do not only shape the design and implementation of a mobility hub, but also expectations regarding effectiveness.

The policy analysis shows that overarching goals are broadly shared and translated into municipal strategies. Within this translation, context-dependency is an important factor, where research of Hachette and L'Hostis (2023) explains that mobility hubs cannot be considered as one-size-fits-all-strategies. Even though similar objectives are valued, mobility hubs should be adjusted to their environment and context. Urban density, spatial considerations and existing mobility systems strongly influence these objectives. This research zooms in on urban areas, where reclaiming public space and addressing parking pressure are often of high priority. More rural areas might value accessibility and connectivity as main drivers in mobility hub development. These findings are argued in literature, where the development of a mobility hub is not a universal development but adapted to environmental context and policy priorities.

Also, the research highlights that ambitions are often not translated into functional operationalisation. Policy documents formulate rather qualitative goals, leaving room for interpretation for assessing its effectiveness. As a result, effectiveness is mostly assumed rather than explicitly defined for empirical assessment. This tendency was revealed in the theoretical framework, where it was explained by Rongen et al. (2022) that mobility hubs are often assumed to be overall remedies for addressing societal challenges. In this light, literature explains that high policy ambitions are not always matched to clear evaluation of actual effects. The findings therefore express the importance of translating strategic ambitions into assessable indicators, especially since mobility hubs have gained high policy interest. This highlights the gap between explicitly linking policy objectives to evaluation criteria in mobility hub development.

From monitoring to evaluation in current assessment practices

Through literature studies and empirical research, it was revealed that current assessment practices by municipalities and provinces are often limited. Even though municipalities are increasingly collecting more data on shared mobility usage and trends in usage, the practices do not reflect the clear impact of mobility hubs on societal challenges. These limitations were mostly evident due to evaluation being in progress or having limited data. Current evaluation practices thus often focus on user data instead of impact on policy objectives and long-term effects on the mobility hub environment. This also highlights the gap that current evaluation efforts tend to focus on the fitting implementation and usage of mobility hubs rather than on impact.

Current monitoring through user dashboards such as the Deelmobiliteit (Shared mobility) dashboard by the knowledge institute CROW provides such quantitative data sets on usage. This enables monitoring and comparison of user numbers between different mobility hubs. However, this highlights the distinction between monitoring and evaluation, where observed changes need to be monitored to interpret and assess changes in regard to predefined goals. Additionally, the role of knowledge sharing is explained within this research. Municipalities and provinces participate in experience-based knowledge sharing, stimulated by the national government. Municipalities express the value of such efforts due to learning lessons from similar situations. However, these efforts could be integrated into structured evaluation approaches, which is often still fragmented or absent.

Evaluating effectiveness through impact indicators

One of the contributions of this research is exploring assessment through impact indicators. This research lays the foundation for creating a generic ex-post evaluation framework based on overarching policy objectives of municipalities collected in literature and expert input. The distinction between usage effectiveness to enhance usage and policy effectiveness to achieve policy objectives is presented. The research identifies that evaluation indicators should explicitly address assessing societal impact rather than usage statistics.

In order to categorize the societal impact to which the indicators contribute, the research presents spatial quality, sustainable accessibility and inclusive cohesion as key themes. These decisions in creating impact indicators align with literature to move towards broader societal impact of mobility interventions. However, the research reveals that indicator-based evaluation also includes some limitations.

Firstly, an important consideration when assessing effectiveness through the proposed impact indicators is causality. In this light, the scale of indicator measurements makes sure with what difficulty a causal relation can be established. Indicators measured on hub level explain the direct changes in the environment of the hub, such as how space is reallocated after the hub development. However, indicators that are measured on city wide or regional level such as modal shifts make sure that establishment of such causality is more difficult. Hereby, the findings illustrate that it is rather complex to attribute observed changes directly to the implementation of a mobility hub, due to other external influences. Especially in complex urban environments, where different developments are used to create mobility changes. Therefore, the research does not imply direct impact for indicators that are measured beyond hub level. The research explains that this does not mean that there is no causal relation between the mobility hub development and the indicator, but that additional research needs to be performed to see to what extent this change is attributable to the hub development.

Another finding in the research bridged the environmental context of a mobility hub and its policy objectives. The research demonstrates that benchmarks can be used for indicator relevance. This allows

municipalities to value indicators based on their relevance in achieving desired policy objectives. Additionally, it was explained that some effects might be of insufficient impact for one while they are unrealistic for others. This finding highlights the need for a flexible evaluation method, where interpretation in environmental context and relevance in policy goals is key. By explicitly acknowledging these considerations, the research avoids generalisation of mobility hub assessments due to context-dependency.

Lessons from application in a dense urban context
The research shifted towards recognition that solely focusing on a generic impact-based evaluation often lacks to address the complexity of context-dependent mobility hub developments. Literature already revealed that the environment of a mobility characterises the functioning and its purpose. Also, exploring a direct causal relation between the development of one single mobility hub and the observed outcomes is challenging for larger scale indicators. Therefore, the findings reflect that assessment should focus on more than just observed effects and focus also on motivations and behavioural changes. Instead of assessing whether a mobility hub directly causes a specific outcome, create a reflection if mobility hubs contribute to achieving policy objectives. By considering these principles in assessment, uncertainty and complexity is acknowledged, especially due to the context-dependent nature of mobility hubs. However, assessment on the causality of indicators at the hub level can be performed directly. Overall, the proposed framework aims to translate theoretical framing to evaluation principles that are usable in different mobility hub contexts. This is particularly considered relevant given the scarcity of ex-post evaluation frameworks for mobility hubs identified in existing literature.

Further, the research explored this concept by applying the framework in one real case application. In this case application, the mobility hub was implemented in a dense urban context which demonstrates one urban mobility context. By applying the framework in one specific urban context, insight was gained on practical usability and potential limitations. As aligned with previous considerations, application of the framework shows that it should align with hub characteristics, local environment, policy objectives and data availability. Here, the dense urban area expressed clear challenges such as spatial pressure and illustrates that some indicators have more relevance than others. Dense urban areas are complex environments, where different external factors potentially influence mobility behaviour.

Additionally, the case application underscores the importance of additional complementary qualitative research. The proposed framework is mainly of quantitative nature and lacks understanding of motivations, perceptions and behavioural dynamics which would enhance findings. Furthermore, qualitative research could explore to understand which aspects motivate people to use mobility hubs or what would dis-encourage them for using mobility hubs. This finding aligns with evaluation literature which emphasizes the value of using mixed methods for assessment. Finally, the case application cautiously addresses whether hubs should be adjusted when effectiveness is not realized or that objectives should be shifted. Here, it is explained that even if a hub is designed perfectly according to usage effectiveness standards, people can still be unmotivated to use hubs. This aligns with the concept that motivations should be explored in qualitative research. This research acknowledges this conflict whether mobility hubs should be adjusted to contribute to goals or adjusted to create the best local integration. However, the research does not address this gap but merely acknowledges it.

7.2. Contribution to literature and policy practice
Overall, this research makes several key contributions to academic literature on ex-post mobility hub evaluation. These findings aim to fill the knowledge gap regarding performing ex-post evaluation on mobility hubs and contribute to several academic debates which are described in the literature review of this research. Firstly, it addresses the gap in existing studies by proposing a systematic evaluation process with the use of a generic evaluation framework. This contributes to the debate in literature that ex-post evaluation is limited and should be considered to make sure that more insight is gained on the actual impact of the development. Secondly, it highlights that the causal societal impact for broad measured objectives of a mobility hub is rather difficult to acquire solely based on the proposed quantitative framework. This contributes to the scientific debate described in the literature that mobility hub interventions cannot be measured without considering their surrounding context. Furthermore, it demonstrates how the context-dependent nature of mobility hubs can be embedded within the generic evaluation framework. It was revealed that focus should be put on mobility hubs characteristics and

relevance of indicators on local policy context when applying the generic framework into practice. This finding contributes to the discussion in the literature that mobility hubs are not uniform interventions but vary significantly in scale, function and environment.

By developing and testing the application of a generic ex-post evaluation framework, the research provides a practical tool that could benefit municipalities to move from monitoring to structured evaluation. Besides, it creates a better understanding of how effectiveness should be adjusted to context and evaluated interpretive. Instead of assessing mobility hubs through a one-size-fits-all approach, different considerations should be taken into account. This research emphasizes the importance of critical reflection on the objectives and nature of a mobility hub before evaluation. By creating this reflection, a better-informed approach can contribute to improved policy learning. The research aims to make uncertainties and assumptions explicit to encourage policy learning rather than solely concluding on its perceived success. It is highlighted that data availability and accessibility serve as key conditions for using the framework.

In conclusion, this research uses evaluation as a tool for critical reflection on contributions to enhance policy practice. Contributions to literature on the considerations of mobility hub evaluation and translation to an applicable framework make sure that the research contributes to better informed and adaptive approaches in mobility hub development.

7.3. Validity

A critical reflection on validity is desirable given the exploratory and context-sensitive nature of this research. Validity needs to be incorporated in this research to make sure that findings can be trusted based on grounded evidence and that it is not misleading the reader (Karnia, 2024).

First of all, construct validity is considered which is the degree to which a tool measures what it is supposed to do (Jordan, Osborne, & Buchbinder, 2010). This was strengthened by linking policy objectives to measurable indicators which derived from literature studies, policy documents and expert interviews. Triangulation is used which refers to that multiple data sources have been used to develop an understanding of a certain phenomena in qualitative research (Carter, Bryant-Lukosius, DiCenso, Blythe, & Neville, 2014). Therefore, the research reduces the risk of only relying on isolated perspectives and enhances the construct validity. The structured translation from abstract policy ambitions to operational indicators supports alignment between literature concepts and empirical assessment.

Further, internal validity refers to whether the study answers the research questions without bias (Andrade, 2018). Internal validity is enhanced due to several measures which are taken in the research to reduce bias. Since triangulation is used, multiple data sources have been conducted to avoid single perceptions and perspectives. This allows the findings to be checked from different viewpoints. In addition, interview questions were semi-structured which leaves room for clarification while providing consistency across the answered questions. Finally, assumptions which were made on for example data availability were made explicit, which shows transparency on what is empirically grounded and what was assumed during the research. Overall, it was aimed to ensure that conclusions were grounded while also being transparent on researcher assumptions.

Finally, external validity refers to whether the research findings could potentially be generalised to other contexts (Andrade, 2018). In this light, the research aims to move away from generalisation of the framework and towards analytical transferability. However, due to the context-dependent nature of mobility hubs and the research involving a single case application, this tendency is present in the research. However, the research aims to make this context-dependency explicit and recommends critical reflection when applying the framework to another mobility hub. Therefore, the study does not claim uniform applicability and highlights the context-dependency. This enables other municipalities to critically assess how the framework can be used in their own context. By explicitly outlining the assumptions, considerations and contextual characteristics of the case, the research supports informed adaptation rather than direct replication.

7.4. Research limitations

Even though the research aimed to create a comprehensive evaluation method for assessing mobility hubs, some limitations have influenced the research. These limitations are acknowledged in the text below, where it explains how this affects the findings in terms of application and potential generalisation.

- Limited data availability
  One significant limitation in this study was the access to data. Therefore, no insight could be gained on the usage of mobility hubs. Also, since no data was available, whether the needed data for the input of indicators was actually easily accessible is assumed through other reports and sources. Thus, it can not be established to what extent data availability was actually accessible for the municipality of Amsterdam. Due to privacy concerns, restricted data and administrative barriers, collecting detailed usage data and insight on trends was not possible. Besides, no actual application of the framework could be performed on realised mobility hubs. This results in that the feasibility of applying the evaluation framework is based on assumptions rather than actual practical application. Overall, the limited data availability has resulted in the research not being able to fully validate how the evaluation framework can be performed in a real-life case application analysis.

- Single case application application
  Within this research, the evaluation framework was tested on one specific case of a mobility hub in Amsterdam. This mobility hub has its own specific urban context and dynamics and thus solely considerations can be made for hubs with similar urban context. Mobility hubs in other municipalities or regions, especially placed in rural areas, may experience different results in application and its challenges. In this light, context-specific mobility hubs have been stressed multiple times through this research but it lacks to provide a comparable analysis in the case application. Therefore, no firm conclusions can be made whether the application is applicable for other contexts due to a lack of validation. This might result in other considerations and adjustments in the application of the evaluation framework for different contexts.

- Focus on direct results
  Within section 5.3 the distinction between impact is made in different time dimensions. Hereby, the evaluation framework focuses on direct results that occur within one year of observable effects of a mobility hub. Therefore, this research mostly focuses on evaluating measurable direct results that focus on observable effects. However, to fully understand how mobility hubs influence mobility behaviour and the liveability of an area, long-term effects need to be explored. Since long-term effects are rather hard to explore within the scope and time constraints of the research, this decision for direct results has been made. Nevertheless, to gain a better understanding of the contribution of a mobility hub to achieving broad policy goals, long-term studies could be performed.

- Lack of qualitative data
  The research is mostly based on assessing quantitative data for evaluating. This is evident in the way the evaluation framework is set up, where quantitative indicators are used such as the number of trips. Although the research uses quantitative data, adding qualitative data would enhance a further deepening of the framework. Especially goals such as inclusive cohesion and spatial quality can also be explained to user experiences, attitudes and appreciations. Without this deeper understanding of how users interact with mobility hubs and their preferences, the research might not fully capture the social aspects behind mobility hub performace.

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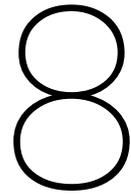
Conclusion

This chapter will answer the research questions as defined in the introduction. Firstly, the different sub-questions are answered that all explore different components of the main question. Afterwards, the main question will be answered with the knowledge from each sub-question. Overall, this chapter will conclude the findings of this research on how ex-post evaluation can be set up for municipalities to assess the performance of mobility hubs on policy goals.

8.1. Answering sub-questions

First, each sub-question will be answered through the findings of this research. This allows to gain more insight on how different components were analysed and what output contributes to the aim of this research.

8.1.1. Policy ambitions

RQ1: Which policy goals and objectives underlie the development of urban mobility hubs projects across the Netherlands?

The first sub-question aims to identify underlying policy goals and objectives that motivate the development of urban mobility hubs. Hereby, first the general goals and objectives are analysed and then a zoom-in was made to the translation to municipal policy documents. This analysis showed that mobility hubs have emerged as multifunctional strategic tools rather than solely a transportation infrastructure. Across municipalities, mobility hubs are often associated with ambitions that face societal challenges such as improving accessibility, stimulating a sustainable movement by creating a modal shift away from private car use and addressing limited public space. While these overarching goals are mostly shared, the interpretation and prioritization of these goals into policy documents vary due to differing spatial, social and mobility-related challenges as well as on urban density.

In urban contexts, objectives are often linked to spatial challenges such as reducing parking pressure and enhancing use of public space. Policy goals vary depending on municipal context, where some municipalities position hubs primarily as accessibility nodes to improve accessibility and connectivity on regional level. Others focus on larger goals such as environmental benefits and spatial quality. This is mostly due to the context-dependent nature of mobility hubs, where they do not serve general purposes, but are adapted to municipal policy priorities and urban context.

Within this research an in-depth policy analysis for the municipality of Amsterdam illustrated how ambitions were operationalised into a dense urban context where a transition towards a car-reduced and liveable urban environment was key. These documents illustrate the link between mobility hubs and reducing parking pressure, limiting private car ownership and reallocating public space to greenery, cycling and pedestrian space to enhance liveability.

Furthermore, this sub-question also revealed that the ambitions and expectations of hubs are often formulated in qualitative objectives, where room is left for translating these objectives into concrete mea-

surable indicators. This makes it rather unclear how evaluation on actual effectiveness of mobility hubs in achieving intended goals should be performed. Here, it highlights that a gap exists between strategic ambitions and outcomes from evaluation. In this light, literature demonstrates that effectiveness is implicitly assumed in objectives rather than explicitly defined. This finding reveals the importance of linking policy objectives more directly to evaluation criteria to enable ex-post assessment. Especially in dense urban contexts such as Amsterdam, where the multilayered goals are set for mobility hubs to address societal challenges.

Overall, this sub-question reveals that the development of mobility hubs is often driven by broad and ambitious policy goals. However, these goals are mostly formulated on strategic level, leaving room for interpretation in assessing measurable outcomes. Revealing the need for an evaluation method that is sensitive to context and expected policy objectives.

8.1.2. Current mobility hub assessment

RQ2: In what way do municipalities assess the performance of realised mobility hubs?
The second sub-question examines how municipalities currently assess the performance or realized mobility hubs. Findings from expert interviews and policy analysis reveal that while municipalities engage in monitoring activities related to mobility hubs, systematic and structured evaluation remains limited on their societal impact. Even though municipalities collect data related to shared mobility usage, these measurements do not explicitly reveal their connection to predetermined policy goals of that hub.

Assessment of performance is often embedded in broader mobility monitoring rather than focusing on evaluation of effectiveness of individual hubs. Consequently, performance assessments focus on user statistics such as occupancy rate, rather than on societal impact. In this monitoring, knowledge institution CROW provides a dashboard that provides municipalities with data on shared mobility usage and related indicators. This allows municipalities to monitor trends over time and to compare user statistics across different mobility hubs. Hereby, insights can be gained on observable effects such as usage patterns and spatial distribution of shared vehicles.

However, this analysis of such databases is often focused on user-based monitoring and lacks evaluative interpretation on policy goals. Hereby, dashboards and data sets are quantitative insights but do not explicitly relate to policy objectives. These monitoring efforts do thus not assess whether mobility hubs contribute to desired outcomes such as a shift from private car usage and hereby reducing car dependency. Furthermore, these quantitative user data do not represent societal impact within current assessment practices.

In addition to monitoring data through dashboards and data sets, knowledge sharing between municipalities and provinces plays an important role in an understanding of how performance is experienced. Within this knowledge sharing, municipalities and provinces often exchange experiences, development strategies and pilot projects. This knowledge sharing is supported by the national government which finances hubs partially in return for gaining new knowledge on mobility hubs. Within these meetings, lessons are learned through gaining insight on practical experiences and on how similar challenges are addressed. Nevertheless, this knowledge sharing is generally sharing experiences than systematically embedding formal evaluation frameworks. The Ministry of I&W is currently working on a national evaluation procedure for mobility hubs, for which this knowledge is crucial input.

Overall, the answer to this sub-question reveals that even though data collection and monitoring user statistics are available, municipalities currently have limited assessment on how to translate outcomes into meaningful policy effectiveness insights. This highlights the need for an evaluation method that connects existing data sources and knowledge sharing to assess the societal impact of mobility hubs in regard to their policy objectives. This would enable municipalities to make the step from observation to structured ex-post evaluation.

8.1.3. Evaluation framework indicators

RQ3: Which indicators can be applied to assess the desired effects of a realised mobility hub?
The third sub-question explores which indicators can be applied to assess the desired effects of realized mobility hubs. Here, the literature from Chapter 3 and the results from the expert interviews

functioned as input for creating indicators for assessing the performance of mobility hubs on policy objectives. Before creating these indicators, a distinction was made between effectiveness from the usage perspective and effectiveness from a policy perspective. This distinction was based on whether aspects resulted in effective use of mobility or effectiveness in achieving policy objectives. In this light, aspects of usage effectiveness would result in more usage of mobility hubs according to governmental representatives and developers and were labelled as enabling factors. These enabling factors were illustrated in 5.2.2 and can be used in development to enhance usage of mobility hubs.

However, the indicators for the evaluation framework which is proposed in this research were based on effectiveness from a policy perspective. Before setting up these indicators, the policy objectives from the literature and interviews that would contribute to policy effectiveness were combined. The findings resulted in a structured set of indicators, deriving from policy objectives and existing monitoring practices. These enable municipalities to assess the observable effects of a mobility hub in a consistent way. Within this set of indicators, a distinction was made in impact category. Here, each indicator would contribute to changing an impact category, the categories are spatial quality, sustainable accessibility and inclusive cohesion. Overall, the indicators form the basis for creating a generic ex-post evaluation that can be applied across municipalities.

Thus, the evaluation framework which is created in this research aims to assess the most mentioned objectives within literature and empirical research. Therefore, the framework focuses on different aspects that are considered when assessing effectiveness from a policy perspective for mobility hubs. For applying the indicators within the framework, the research highlights the strong influence of data availability and scale. The indicators in the framework are of quantitative nature and rely on data sources that should be accessible to municipalities.

Besides data availability, some other considerations are made within the operationalisation of indicators. The scale of the indicators varies, where some indicators measure hub specific output, while other indicators are measured on a broader scale such as city or region wide. Indicators that are measured in a larger area have more difficulty with attributing direct causal relationships due to other external factors that might influence indicators such as a reduction in private car dependency. This consideration underscores that such indicators need additional research to establish the actual causal effect. Additionally, the findings specify that benchmarks of indicators are dependent on the policy objectives of municipalities, where some municipalities value smaller impacts than others. Overall, these indicators can be used for generic evaluations of mobility hubs, where indicators should be adjusted to the specific policy and context-nature of mobility hub aspects and objectives.

To conclude, the answer to this sub-question reveals that indicators can be applied as input for a generic ex-post evaluation framework for mobility hubs. Here different considerations are provided due to the context-specific nature of mobility hubs and the precondition of data availability. By incorporating these considerations, the indicators enable municipalities to assess the potential effects of mobility hubs on policy objectives, while allowing flexibility for municipal interpretation and policy priorities.

8.1.4. Evaluation framework application through case application

RQ4: How can the effects of a selected urban mobility hub in Amsterdam be assessed through a developed evaluation framework?

Finally, the fourth sub-question explored how the developed evaluation framework could be applied in practice and which lessons can be drawn from its application in a dense urban context. This was assessed through a case application that analysed the mobility hub Appeltjesmarkt in the city centre of Amsterdam. In this case application the goal was to see whether the framework provides an applicable structure for evaluating the effects of mobility hubs in a complex urban environment.

Within this assessment, the findings of the case application revealed that for putting the evaluation framework into practice some adjustments and considerations needed to be incorporated to provide a fitting assessment. Firstly, the indicators need to be aligned with the hub aspects, making sure that indicators consider different elements of the mobility hub and its environment. For example, the pressing parking pressure in Amsterdam demonstrated that reducing parking spaces might not be favourable. Furthermore, the case application showed that indicators should be adjusted to relevance according to hub objectives. Here, it was explained that Amsterdam's policy agenda ensures that

some indicators have greater relevance in the mobility hub objectives than others. Finally, the practical feasibility of the framework to assess the mobility hub Appeltjesmarkt showed how data availability was partially dependent on receiving data from external stakeholders. Additionally, it was revealed that in order to make valuable insights into motivations, attitudes and behavioural changes, additional qualitative research would further deepen the quality of the framework.

The application within the case application highlights limitations of performing ex-post evaluation with the proposed quantitative evaluation framework in attributing observed changes measured beyond hub level directly to mobility hub developments. Other external factors influence mobility trends as well and the motivations behind using a mobility hub or not are also mentioned as considerations. In order to make firm conclusions on whether the mobility hub would contribute effectively to these objectives, additional research is needed to explore for example motivations behind mobility behaviour. However, the framework makes these uncertainties explicit rather than eliminating them, supporting a reflective interpretation rather than definitive conclusions. Additionally, direct assessment can be performed for indicators that are measured on a mobility hub scale such as reduction of nuisance and enhancing public space at the hub location.

Overall, the case application demonstrates that the evaluation framework functions as a practical and transferable tool for assessing the effects of urban mobility hubs. The key lesson is that the framework enables structured reflection on effectiveness while acknowledging contextual complexity. The framework explains its value as a continuous learning tool rather than a conclusive performance assessment.

8.2. Answering main research question

Main research question: *"How can the effectiveness of realised urban mobility hubs be assessed through an ex-post evaluation framework, in relation to their intended policy goals?"* Overall, this research aims to explore effectiveness of realised mobility hubs through an ex-post evaluation framework that translated policy objectives into measurable indicators. In this evaluation, it was aimed to explicitly account for contextual interpretation and methodological limitations. It was revealed that the framework serves as an analytical tool that explores effectiveness in terms of contribution to policy goals. The framework was applied to an urban context, demonstrating how application can be adapted to a specific context.

Moreover, the proposed evaluation framework served as a generic evaluation tool that can be used to assess observable effects through a set of indicators that are linked to policy objectives. These indicators have been developed according to a policy analysis and the results of expert interviews, where the goal is to measure effectiveness of policy objectives. By creating these indicators, impact is categorised in spatial quality, sustainable accessibility and inclusive cohesion. Furthermore, these indicators allow municipalities to explore how mobility hub developments could potentially contribute to observable changes. Indicators can be assessed through mostly existing monitoring systems, where acquiring the right data is essential. Here, the scale of indicators is of high importance, where some indicators explain changes on hub level while others account for regional or city-wide changes.

At the same time, this research demonstrates that the proposed ex-post evaluation requires careful interpretation. Since some indicators are measured on a scale larger than mobility hubs, the complex influence of external factors also affects observable effects. Therefore, it is rather difficult to establish direct causal relations of these effects such as modal shifts. Since the framework is of quantitative nature, potential impacts need to be supported with additional research to explore whether measured changes occur due to mobility hub developments. Nevertheless, some indicators such as vehicle occupancy and accessibility features can be measured directly. This results in a framework that aims to explain measurable impact on mobility hub level changes and explore contribution of mobility hub developments on larger scale effects in for example mobility behaviour.

Further, the framework acknowledges the context-dependent nature of mobility hubs in effectiveness. This context-dependency frames application of framework indicators to hub aspects, relevance in policy objectives and applicability in data availability. This is relevant for addressing contextual differences and illustrates the adaptability of the framework to a more specific context. Hereby, it allows municipalities to adapt a generic framework to their own local priorities. This allows flexibility in indicator selection, benchmarks for indicators and interpretation of assessment while maintaining a consistent evaluation

structure. Additionally, the role of adding qualitative indicators for explaining changes in behaviour is established of high potential in future research.

In conclusion, the effectiveness of achieving policy objectives for realised urban mobility hubs can be assessed through an ex-post evaluation framework. This framework uses policy-driven indicators in assessment while incorporating contextual interpretation. Overall, this approach enables municipalities to gain more insight on how mobility hubs perform explicitly on mobility hub level and how they potentially contribute to larger scale effects. Therefore, the framework recognises complexity and uncertainty in assessment and highlights the necessity of accessible input data. The framework can serve as a valuable tool to enhance policy learning and reflect on mobility hub developments with well-informed considerations.

8.3. Recommendations for municipalities

Based on the finding of this research, different recommendations can be made. Hereby, recommendations are made for municipalities that aim to explore ex-post mobility hub evaluation or to apply the proposed framework.

- Ensure data availability for measuring indicators
  Ensuring data availability has been proven of high importance for exploring the indicators that are set up for evaluation. Due to the quantitative nature of the evaluation framework, it is essential to ensure that adequate data is secured. The case application revealed that some data for the indicators should be acquired through external stakeholders such as shared vehicles providers and data institutes such as the CBS. By improving data collection, standardised data sets can be used to evaluate performance indicators. Overall, through ensuring data availability, better informed assessments can be informed through a reliable data input.

- Context sensitive evaluation principles
  Given the context-specific nature of mobility hubs and the evaluation of these hubs, it is recommended to let assessments be performed by mobility hub experts. If the application of the framework is performed by someone who does not have adequate knowledge on hub aspects, environmental context and municipal policy priorities, the application of the evaluation framework could be wrongfully interpreted. Thus, context-sensitive aspects should be carefully considered when assessing mobility hub performance, also when the framework is not used. Mobility hubs should be conceptualised as integrations within a municipal mobility system and considered through their aspects.

- Include user feedback in evaluation
  To ensure that mobility hubs meet user needs and expectations, it is important to integrate user feedback into the evaluation process. Surveys, focus groups, and interviews with local residents can provide valuable insights into the perceived benefits and challenges of hubs. Understanding how users perceive the hub's convenience, accessibility, and integration with their daily routines can help adjust services and improve overall user adoption.

- Active participation in knowledge sharing
  This research has discussed how different municipalities and provinces contribute to knowledge sharing of mobility hub developments, which is supported by the national government. When municipalities start structural evaluation of the impact of mobility hubs on societal challenges and policy goals, knowledge sharing can become crucial. Since stakeholders face similar challenges when assessing mobility hubs, lessons can be shared on how to address these challenges. By doing so, more standardisation can be created across evaluations, which could contribute even more effectively to national efforts of mobility hub development. Also in the light of context-sensitivity, lessons can be shared on how to efficiently address this matter in evaluations.

8.4. Future research

Even though this research has contributed to valuable insights on mobility hub development, several directions for future research are recommended. These future research directions mostly address the limitations of this research and how this can be further investigated.

- Long-term impact evaluation
  Since this research focuses on evaluating direct results that can be measured in a relatively short period of time, future research could further analyse long-term impact of mobility hubs. This research direction could include analysing long-term structural shifts in mobility behaviour, evolution of private car dependency with increasing sustainable alternatives and the long-term spatial effects of mobility hub integration. Additionally, correlation with other interventions can be explored. For example, it can be explored which influence public transportation and shared mobility have on achieving objectives.

- Comparative case study analysis
  As mentioned within the limitations, this research only included one selected case in the case application. To gain a better understanding of different environmental contexts, future research could explore beyond the chosen urban context. Not only can different contexts be compared, but also similar contexts. By comparing two similar contexts in evaluation, different challenges in application such as data collection might be faced or different considerations can be added. Overall, creating a comparative case study analysis could enhance the practical application of the evaluation framework. Also, it could potentially contribute to standardising evaluation aspects in similar contexts.

- User behaviour and enablers
  Besides from collecting quantitative data, a deeper understanding of user behaviour is critical for further improving mobility hub development. Future studies such as surveys could explore which aspects in design and functioning could influence the usage of a mobility hubs. This could potentially reveal which enablers can be created for effective use of mobility hubs by targeted users. Social factors such as demographics can be used to see how different groups have different preferences for mobility hubs. This could then create guidelines for attracting certain people to use mobility hubs. Understanding why people to choose to incorporate a mobility hub in their mobility behaviour or not can inform policy makers and developers to better meet those needs.

- Integration of emerging advanced technologies
  The interview with respondent 2 revealed that some people have an adverse attitude to using mobility hubs due to complicity of usage. By adopting emerging advanced technologies such as MaaS applications, usage can be made even more accessible. Nevertheless, better integration of advanced technologies does not only contribute to better accessibility, it can also contribute to better monitoring. Future research on how digital platforms and data-sharing technologies can be used for real-time and evaluate monitoring, could ease evaluation efforts through advanced and smart data collection.

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A

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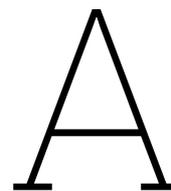
Interview protocol

</div>

The following protocol was used when interviewing the respondents. However, in order to keep the interview dynamic and to address emerging themes, differing follow-up questions have been asked to gain more insights. Firstly, the exploring interview questions with the municipality of Amsterdam are shown, afterwards the in-depth interviews with the other interviewees.

A.1. Exploring interviews municipality of Amsterdam

1. **Introduction**

   - Own introduction
   - Introduction of interviewee
   - Introduction to the project
     - Project overview
     - Goal of the project
     - Overview of interview topics

2. **Confidentiality and data use**

   - Discuss informed consent form
   - Permission for audio recording and transcription
   - Processed data will be send for reviewing

3. **Involvement in mobility hub field**

   - Can you describe your role and involvement in the field of mobility hubs?
   - Can you elaborate on your experiences with the development of mobility hubs in Amsterdam?

4. **Development of mobility hubs**

   - What are the underlying motivations for the development of mobility hubs?
   - What effects do you think are aimed for in the development of a mobility hub?
   - What does the development process of a mobility hub look like?
   - What developments have taken place in this area in Amsterdam in recent years?

5. **Functioning of realised mobility hubs**

   - What collaborations between stakeholders are taking place in the development and management of mobility hubs?

- In your experience, how do different contextual aspects such as environment and services offered influence the design and functioning of a hub?
- What challenges are experienced in the functioning and management of hubs?

6. **Evaluation of realised mobility hubs**

- What are the expected long-term effects for mobility hubs?
- Have certain needs or opportunities been identified that future hubs could potentially respond to more effectively?
- Is there currently any form of performace evaluation for developed hubs?
- How are hubs monitored and evaluated over time, and how is this feedback used to improve developments?

7. **Closing**

A.2. Interviews with other respondents

1. **Introduction**

- Own introduction
- Introduction of interviewee
- Introduction to the project
    - Project overview
    - Goal of the project
    - Overview of interview topics

2. **Confidentiality and data use**

- Discuss informed consent form
- Permission for audio recording and transcription
- Processed data will be send for reviewing

3. **Involvement in mobility hub field**

- Can you describe your role and involvement in the field of mobility hubs?
- Can you elaborate on your experiences with the development of mobility hubs in ...?

4. **Development of mobility hubs**

- What are the underlying motivations for the development of mobility hubs?
- What effects do you think are aimed for in the development of a mobility hub?
- What does the development process of a mobility hub look like?
- What developments have taken place in this area in Amsterdam in recent years?

5. **Functioning of realised mobility hubs**

- What collaborations between stakeholders are taking place in the development and management of mobility hubs?
- In your experience, how do different contextual aspects such as environment and services offered influence the design and functioning of a hub?
- What challenges are experienced in the functioning and management of hubs?

6. **Evaluation of realised mobility hubs**

- What are the expected long-term effects for mobility hubs?
- When can a hub be labeled as effective in your perspective?
- In what way are hubs monitored and evaluated over time?
- How is this feedback used to improve developments?

- Which elements should future evaluation of hubs contain?

7. **Closing**

A.3. Interview with Ministery of I&W on evaluation

1. **Introduction**

   - Own introduction
   - Introduction of interviewee
   - Introduction to the project
     - Project overview
     - Goal of the project
     - Overview of interview topics

2. **Confidentiality and data use**

   - Discuss informed consent form
   - Permission for audio recording and transcription
   - Processed data will be send for reviewing

3. **Evaluation of mobility hubs**

   - What is the current phase of conducting national evaluation?
   - Which motives lead to the initiation of this process?
   - Which themes are important within the evaluation?
   - Which data gathering methods are used and what is the source?
   - When can a mobility hub be labeled as effective in your perspective?
   - What challenges have emerged while performing evaluation on hubs?

4. **Closing**

B

Data ethics applications

Since data is gathered and processed during this research, data ethics needed to be considered. Therefore, different documents have been set up in line with the TU Delft ethics guidelines. Firstly, an informed consent form will be shown which was signed by all respondents before conducting the interview. Afterwards, a data management plan will be incorporated which shows the different ways of how data is gathered, why this data is gathered and which precautions and measures are taken by doing so.

B.1. Informed consent form

Informed consent form

You are being invited to participate in a research study titled "Evaluating the effectiveness of urban mobility hubs: an ex-post assessment of underlying policy goals"
This study is being done by Lisa Rijnbeek from the TU Delft under supervision of Bernice den Haan (APPM) and Erik-Jan Houwing (TU Delft).

The purpose of this research study is to explore the performance of urban mobility hubs, regarding the underlying policy goals. Participation within this research will take you approximately 60 minutes to complete. The data will be used for gaining insights on stakeholders' ambitions towards mobility hubs and to evaluate the potential effects of mobility hubs. We will be asking you to provide insights in your decision-making and/or point of views.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by storing the data in an enclosed cloud environment and storing the data anonymized. After this research, all data will be deleted from the drive.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. Data will be returned for reviewing, from which data can be removed until two weeks after sharing.

Thank you very much for your participation, feel free to ask any questions.

Lisa Rijnbeek

Erik-Jan Houwing (Responsible supervisor)

Explicit Consent points

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated __/__/____ (DD/MM/YYYY), or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: • Answering questions on the policy plans and evaluation of mobility hubs • That the interviews will be recorded and transcript, which will be stored in the TU Delft OneDrive. Recordings will not be shared or used within the report and will be deleted afterwards • Transcripts will be anonymised and shared with the participant. Modifications can be made, and this will be used within the research	☐	☐
4. I understand that the study will end around the beginning of March 2026 and that the anonymised data will be used	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. I understand that taking part in the study involves the following risks: sharing personal information and data loss of files or transcripts. I understand that these will be mitigated by anonymizing and storing the data properly within the TU Delft OneDrive.	☐	☐
6. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) such as age, job description or other socio-demographic aspects and associated personally identifiable research data (PIRD) with the potential risk of my identity being revealed.	☐	☐
8. I understand that some of this PIRD is considered as sensitive data within GDPR legislation	☐	☐
9. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach • Data will be stored properly within the TU Delft OneDrive • Interview recordings will be transcript and anonymised, after which supervision will take place on anonymisation by the responsible supervisors of APPM and the TU Delft. • After finalisation of transcription, recordings will be deleted	☐	☐
10. I understand that personal information collected about me that can identify me, such as my contact details or address will not be shared beyond the study team.	☐	☐
11. I understand that the (identifiable) personal data I provide will be destroyed before 01-03-2025	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for analysing the performance of mobility hubs and their preset policy goals. This information will	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
be used for analysis, which can be used for publication of the master thesis and other academic reports		
13. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
14. I agree that my real name can be used for quotes in research outputs, after giving permission for doing so.	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
16. I give permission for the de-identified (anonymised transcripts) that I provide to be archived in TU Delft repository so it can be used for future research and learning.	☐	☐
17. I understand that access to this repository is open.	☐	☐

Signatures

_____   _____   _____
Name of participant [printed]   Signature   Date

I, as legal representative, have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

_____   _____   _____
Name of witness   [printed]   Signature   Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Lisa Rijnbeek
_____   _____   _____
Researcher name   Signature   Date

Study contact details for further information:
Lisa Rijnbeek, ███████████████████

B.2. Data management plan

Plan Overview

A Data Management Plan created using DMPonline

Title: DMP Thesis Lisa Rijnbeek

Creator: Lisa Rijnbeek

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2025)

Project abstract:

Urban mobility hubs are increasingly implemented in the Netherlands as part of sustainable urban development strategies. These hubs are intended to integrate different modes of transport, reduce car dependency. Moreover, the goal is to contribute to broader policy goals such as improved accessibility and lower emissions. Despite their rapid development, limited evaluation has been performed whether the intended policy objectives are being realised.

This thesis conducts an ex-post evaluation of realised urban mobility hubs in relation to their initial policy goals. First, it identifies and analyses the policy objectives that underly mobility hub projects across the Netherlands. Afterwards, it develops and applies an evaluation framework with suitable indicators to assess their effectiveness. The research compares observed outcomes with the initially formulated goals, thereby offering insights into the extent to which mobility hubs meet their intended ambitions.

ID: 186559

Start date: 01-09-2025

End date: 01-03-2026

Last modified: 26-09-2025

DMP Thesis Lisa Rijnbeek

0. Administrative questions

1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.

[Name, Surname of the Data Steward], Data Steward at the Faculty of [Faculty Name], has reviewed this DMP on [date of review].

2. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration – please provide details of the type of collaboration and the involved parties below

Within this project, the TU Delft is the leading institution and APPM Management Consultants is the involved company. Therefore, a consortium is formed which is supported by the signed UNL Graduation Agreement

I. Data/code description and collection or re-use

3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.

Type of data/code	File format(s)	How will data/code be collected/generated? *For re-used data/code: what are the sources and terms of use?*	Purpose of processing	Storage location	Who will have access to the data/code?
Contact information interviewees (Full name and E-mail)	.docx	E-mail / interviews	To get in contact	TUD OneDrive	Me
Informed consent form for interviewees.	pdf.	E-mail / interviews	Ask permission to use data	TUD OneDrive	Me, participants
Voice recordings of interviewees.	.mp3	Interviews through Microsoft Teams or recordings by phone	Used to transcribe interviews	TUD OneDrive	Me
Interview transcripts.	.docx	Interviews by Microsoft Teams	Analyse practical insights	TUD OneDrive	Me
Anonymised interview transcipts	.docx	Interviews	Analyse practical insights	TUD OneDrive	Me, participants, supervisors from TU Delft and APPM
Personally Identifiable Research Data (job description)	.docx	E-mail / interviews	Ensuring role within development	TUD OneDrive	Me
Analysed data used within research	.docx	Analysis	Evaluating mobility hubs	TUD OneDrive	Me, participants, supervisors from TU Delft and APPM

II. Storage and backup during the research process

4. How much data/code storage will you require during the project lifetime?

- < 250 GB

5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)

- TU Delft OneDrive

III. Data/code documentation

6. What documentation will accompany data/code? (Select all that apply.)

- Data – README file or other documentation explaining how data are organised
- Data – Methodology of data collection

IV. Legal and ethical requirements, code of conducts

7. Does your research involve human subjects or third-party datasets collected from human participants?

If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.

- Yes – please provide details in the additional information box below

I intend to apply for ethical approval from the Human Research Ethics Committee.

8. Will you work with personal data? (This is information about an identified or identifiable natural person, either for research or project administration purposes.)

- Yes

I will conduct interviews, within these interviews some personal experiences and roles towards development of mobility hubs is assessed.

9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any other types of confidential or classified data/code

10. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your [Faculty Contract Manager](#) when answering this question.

The intellectual property rights are framed by a graduation agreement between Delft University of Technology, APPM Management Consultants and myself as principle researcher

11. Which personal data or data from human participants do you work with? (Select all that apply.)

- Other types of personal data or other data from human participants – please provide details below
- Proof of consent (such as signed consent materials which contain name and signature)
- Audio recordings
- Job title and/or employer
- Telephone number, email addresses and/or other addresses as contact details for administrative purposes
- Date of birth and/or age
- Gender
- Names as contact details for administrative purposes

Role within development of mobility hubs

12. Please list the categories of data subjects and their geographical location.

Interview participants are stakeholders involved within the development of mobility hubs or the evaluation of it. All participants are located in the Netherlands

13. Will you be receiving personal data from or transferring personal data to third parties (groups of individuals or organisations)?

- No

16. What are the legal grounds for personal data processing?

- Informed consent

17. Please describe the informed consent procedure you will follow below.

The researcher will inform the potential participants about the goals and procedures of the research

project. The researcher will also inform them about the personal data that are being processed and for what purpose. This information will be provided to the potential participants as follows: a digital copy of the information will be emailed to participants before the interview. All participants will be asked for their consent for taking part in the study and for data processing by signing a digital or physical informed consent form before the start of the interview.

18. Where will you store the physical/digital signed consent forms or other types of proof of consent (such as recording of verbal consent)?

TU Delft OneDrive

19. Does the processing of the personal data result in a high risk to the data subjects? (Select all that apply.)

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data in your research project.

If any category applies, please provide additional information in the box below. Likewise, if you collect other type of potentially sensitive data, or if you have any additional comments, include these in the box below.

If one or more options listed below apply, your project might need a DPIA. Please get in touch with the Privacy team (privacy-tud@tudelft.nl) to get advice as to whether DPIA is necessary.

- None of the above apply

23. What will happen with the personal data used in the research after the end of the research project?

- Other – please explain below

Personal research data will be deleted after the end of the research.

24. For how long will personal research data (including pseudonymised data) be stored?

- Personal data will be deleted at the end of the research project

25. How will your study participants be asked for their consent for data sharing?

- In the informed consent form: participants are asked to give their explicit consent for sharing their (pseudonymised) personal data with restricted access with specific recipients for specific purpose(s)

V. Data sharing and long term preservation

27. Apart from personal data mentioned in question 23, will any other data be publicly shared?

Please provide a list of data/code you are going to share under 'Additional Information'.

- No other data/code can be publicly shared – please explain below why data/code cannot be publicly shared

Only anonymised data will be used

VI. Data management responsibilities and resources

33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?
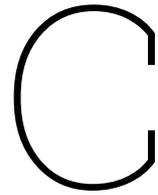
Erik-Jan Houwing

34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

Not applicable

35. Which faculty do you belong to?

- Faculty of Civil Engineering and Geosciences (CEG)

C

Use of Artificial Intelligence

In this thesis, artificial intelligence (AI) has been used to support both technical improvements in Overleaf and provide suggestions for academic writing. AI has played a valuable role in enhancing the overall efficiency of the writing process through advanced tools that refine improve the writing itself.

Firstly, AI was utilized to assist with technical improvements in Overleaf, the platform used for LaTeX editing. AI provided automated suggestions for improving document structure, such as automatically detecting layout inconsistencies or offering alternatives for more efficient code and commands. This helped save time and ensured that the document structure was generated without unnecessary complications.

Additionally, AI played a role in refining the academic language and style of this thesis. By using AI, I received suggestions for improved word choices and sentence structures. This resulted in more coherent and formally written text. AI provided specific examples of how certain sentences could be rewritten for clarity and conciseness.

By integrating AI into the writing process, not only was the technical aspect of document management improved, but the overall readability and academic quality of the thesis was strengthened. AI contributed to a more efficient document set up process while also enhancing the quality of the text, which is useful for higher-level academic writing.