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Innovative transport solutions—
Unravelling challenges in public-private networks

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UNRAVELLING CHALLENGES IN PUBLIC-PRIVATE NETWORKS

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ABSTRACT

New transport solutions and technologies are continuously developed and implemented aiming to reduce emissions, increase road safety, and improve mobility for both people and goods. Solutions with high potential for increased sustainability often depend on multi-actor interaction and public-private collaborations. However, even if the solutions or technologies are considered to have high potential to contribute to sustainable transport systems, they are rarely implemented on a large scale. This thesis aims to contribute to current understanding of challenges of implementing innovative transport solutions that depend on interactions between public and private actors.

The thesis builds upon a qualitative research design based on three studies, a literature review and two empirical studies, exploring three different transport solutions, UCC, MaaS, and geofencing, in their network contexts. The studies focus on challenges of achieving the transport solutions' expected sustainability objectives, network and role dynamics in developing and implementing the solutions, and the perceived value of and barriers to the solutions.

The results of the studies identify three sets of challenges: (1) the challenge of reaching sustainability objectives for innovative transport solutions, (2) the challenge of understanding networks and actor roles in innovative transport solutions, and (3) the challenges with resource interaction and combination for innovative transport solutions. To achieve the desired sustainability effects, better coordination is required within and between organizations and between different developing areas. Understanding of actor roles in implementing new transport solutions needs to be further elaborated. New types of innovation processes could be relevant to achieving the expected sustainability objectives of new transport solutions more efficiently.

Keywords: Public-private interaction, innovation, urban mobility, ICT, networks

List of appended papers

Paper 1: Lindkvist, H., & Melander, L. (2022). "How sustainable are urban transport services? A comparison of MaaS and UCC", *Research in Transportation Business & Management*, Vol. 43, 100829, https://doi.org/10.1016/j.rtbm.2022.100829

Author contribution: The tasks of planning the study and data collection were distributed between the authors. While Lindkvist focused on data collection and analysis for UCC, Melander focused on data collection and analysis for MaaS. Both writers were involved in the writing, reviewing, and editing process.

Paper 2: Lindkvist, H., Lind, F., & Melander, L. (2022). "Actor roles and public-private interaction in transitioning networks: The case of geofencing for urban freight transport in Sweden", *Journal of Business & Industrial Marketing,* Vol. ahead-of-print, https://doi.org/10.1108/JBIM-10-2021-0494

Author contribution: Lindkvist did most of the planning and framing of the study as well as data collection. Lind and Melander assisted with theoretical considerations and analysis. All three authors were involved in the writing, reviewing, and editing process.

Paper 3: Lindkvist, H., Dubois, A., Lind, F., & Melander, L. (2022). "Multiple perspectives on the values of a resource combination—The case of geofencing in freight transport".

Work in progress to be submitted to academic journal. The appended version has been peer-reviewed and presented at the 38th Annual IMP Conference, Aug. 31–Sept. 2, 2022, Florence, Italy.

Author contribution: Lindkvist did most of the planning and framing of the study as well as data collection. Lindkvist and Melander did the majority of the data processing while Dubois and Lind contributed by analyzing the results. All four authors were involved in the writing, reviewing, and editing process.

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> *"A journey will have pain and failure. It is not only the steps forward that we must accept. It is the stumbles, the trials, the knowledge that we will fail. But if we stop, if we accept the person we are when we fall, the journey ends. That failure becomes our destination. To love the journey is to accept no such end. I have found, through painful experience, that the most important step a person can take is always the next one."* – Dalinar Kholin, Oathbringer
>
> (Novel by Brandon Sanderson)

While this quote might sound somewhat dramatic in the context of writing a licentiate thesis, it holds some truths. Being a young researcher there are various challenges that create different stumbles and trials. On one side there are challenges such as meeting deadlines, writing texts, collecting data, and so on. On the other side, you have internal challenges and struggles where there is a lot of questioning of one's capability. But to keep going, taking the next small step, will ultimately result in you reaching your desired destination. In this case, that destination is this licentiate thesis.

To experience and overcome the stumbles on the journey of writing this thesis would not have been possible without the help and support of my supervisors Lisa Melander and Frida Lind, nor the valuable input of Anna Dubois. I cannot get my head around all the brilliance and expertise you three possess. Furthermore, I am grateful to my colleagues at the SOM division for all support and the encouragement to take the next step of my journey.

I must of course mention the importance of my family and friends. Thank you all for being who you are and for all the laughter we have shared. Madde, you know that this thesis is as much your work as mine. Thank you for enduring endless periods of reflection during this process and providing your support and reason.

Lastly, I would like to thank CLOSER and Lindholmen Science Park for giving me this opportunity and for our collaboration. You all continue to inspire me, and I hope we can continue our collaboration wherever our journeys take us.

Hannes Lindkvist
Gothenburg, September 2022

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1. Introduction

1.1 Background

Mobility enabled by cars, trucks, buses, and motorbikes accounts for approximately 15-18% of direct CO_2 emissions (IEA, 2020). Reducing emissions from road vehicles is considered a critical factor in reaching set climate goals. Furthermore, road transport contributes considerable negative effects on public health through road safety as well as noise and air pollution (Sustainable Mobility for All, 2017). Hence, transport is included in various UN Sustainable Development Goals (SDGs) to promote more sustainable transport solutions that contribute to safer, more accessible, and healthier transport environments. Sustainable transport is also included in European policy goals (European Commission, 2020) and national goals (Regeringskansliet, 2021). Mitigating the negative effects of road transport while meeting increasing transport demand will require new transport solutions (Sustainable Mobility for All, 2017). Traditionally, there are two strategies to mitigate the negative effects of transport: behavioral change and technological change (Steg and Gifford, 2005). Both are considered crucial for a transition toward a more sustainable transport system (Pei *et al.*, 2010). Developing and implementing innovative transport solutions to increase sustainability often relies upon collaboration and interaction between multiple actors, including both public and private organizations (Böhm, 2019; Dowling and Kent, 2015; Lindholm and Blinge, 2014; Smith *et al.*, 2019; Weber *et al.*, 2014).

Many different transport solutions that depend on public-private interaction have been developed and tested. These include Mobility as a Service (MaaS), Intelligent Transport System (ITS)-services, urban consolidation centers (UCC), geofencing, off-peak deliveries, and high-capacity transport. Several of these have been tested in various pilots and small-scale projects over a number of years, while others have only become relevant recently. Although many of the transport solutions presented are considered to have high potential to contribute to more sustainable transport, few have been implemented on a large scale (Wiesenthal *et al.*, 2011). Many innovative transport solutions do not achieve their expected sustainability potential for various reasons, such as complex networks (Björklund *et al.*, 2017), a lack of viable business models (Li and Voege, 2017), regulatory restraints (Smith *et al.*, 2019), and user resistance (Tsakalidis *et al.*, 2020). Furthermore, new transport solutions, especially those that incorporate digital technology, present the challenge of unclear roles for actors within the networks, such as how public authorities enable or take part in the new solutions (Tsakalidis *et al.*, 2020).

Over the last decade, digitalization has received increased interest in the transport sector, as it can enable new services and solutions as well as contribute to improving those that already exist (Sjoberg *et al.*, 2017). Furthermore, it is considered to have significant potential to increase transport sustainability by reducing emissions (Chatti, 2021), increasing road safety (Vourgidis *et al.*, 2020), and improving mobility (Olia *et al.*, 2016). However, digitalization entails a number of disruptive and uncertain elements, such as data sharing (Pernestål *et al.*, 2021), policy development (Degrande *et al.*, 2019), public-private innovation (Smith *et al.*, 2019), new business models (Leviäkangas and Öörni, 2020), and new actors entering the market (Böhm, 2019).

While there are comprehensive studies pointing to the importance of collaboration for developing and implementing sustainable transport solutions, there are few academic papers that investigate actor interactions and network dynamics within transport solutions that depend on public-private interaction. As digitalization takes a greater role in enabling new transport solutions, the network of actors involved becomes more complex and the roles and responsibilities of public and private actors become vaguer (Bäumler and Kotzab, 2020; Leviäkangas and Öörni, 2020).

1.2 Scope

This thesis focuses on the challenges of implementing new transport solutions in public-private contexts. For this thesis, a transport solution is defined as a concept, technology, procedure, or innovation to improve the transport of people and/or goods with the aim of contributing to social, environmental, and economic sustainability. Primarily, three transport solutions have been studied: (1) Urban Consolidation Centers (UCC), (2) Mobility-as-a-Service (MaaS), and (3) geofencing. These are all transport solutions that involve a number of actors, rely on public-private interaction, and, to some extent, rely upon or can be supported by digitalization.

A UCC enable consolidation of goods, parcels and other consignments entering or exiting a city or area with the aim to reduce freight vehicle traffic by increasing vehicle load utilization (Olsson and Woxenius, 2014). Commonly it operates in the intersection of urban and inter-urban areas and focus on the last- and/or first-mile distribution of a supply chain. Despite their potential environmental and social benefits, it is common for UCC trials and pilots to end once initial funding is used up or public subsidies are removed (Allen *et al.*, 2012), mostly due to the number of stakeholders involved and the difficulty of defining business models (Björklund *et al.*, 2017).

MaaS is a much newer transport concept that has only been a subject of research for a few years. It puts users' need in center by providing personalized, flexible, and on-demand mobility services by combining different modes of transport (Sochor *et al.*, 2018). MaaS uses a platform that provides a single purchase option that covers multiple modes of transport and mobility operators, hence providing customized mobility service options for individual users. MaaS requires many actors in its development and implementation, ranging from mobility service providers, public authorities, and platform providers (Sochor *et al.*, 2018). For MaaS to provide its intended value, there needs to be coordination between actors and stakeholders in the network, including integration of information, systems, and operations (Ambrosino *et al.*, 2016).

Geofencing is an old technology, but its application to transport and traffic management is relatively new. In relation to transport and traffic, geofencing can be defined as: "*Creation of a geofence for monitoring, informing, and controlling traffic (mobile objects/vehicles) located within, entering or exiting the geofence, using electronic communication technologies or pre-defined geofences embedded into the mobile objects/vehicles, where a geofence is defined as: a virtual geographically located boundary, statically or dynamically defined"* (Hansen *et al.*, 2021). This means that a virtual perimeter detects when a vehicle or other road user enters or exits a geographically defined area and triggers some kind of action in or outside the vehicle, such as a toll payment, switch of powertrain in a hybrid vehicle, warning signaling, or speed adjustment (Foss *et al.*, 2019).

1.3 Aim of the thesis

There is currently little theoretical and empirical research on challenges that interactions in networks impose on implementing innovative transport solutions, especially solutions that depend on public-private interaction and digitalization. Although collaboration between multiple actors has been highlighted as essential to the development, introduction, and use of innovative solutions for increased transport sustainability, there is still little understanding of the networks and interactions surrounding the development and implementation of innovative transport solutions. Not understanding challenges in the interactions required to make the transport solutions work could potentially hinder implementation and potential to increase transport sustainability.

Therefore, the aim of this thesis is:

"To contribute to current understanding of challenges of implementing innovative transport solutions that depend on interactions between public and private actors."

1.4 Outline of the thesis

Chapter 1 presents the background, scope, and aim of the thesis. It explains why new transport solutions are important to enable more sustainable transport systems, the challenges of implementing new sustainable transport solutions, and why understanding public-private interaction in developing these new solutions is important. Chapter 2 describes the theoretical framework, which is then connected to the empirical background in a problem discussion, leading to the research questions of the thesis. Chapter 3 explains the methodology of the thesis by presenting the research design and process as well as the methods used in conducting the different studies. The chapter concludes with some methodological reflections on the research process. Chapter 4 provides a brief summary of the appended papers. Chapter 5 presents the results of the studies in relation to each of the three RQs of the thesis. Chapter 6 then discusses the results from a broader perspective, contributing to a more generalized understanding of the challenges with realizing sustainable transport solutions that depend on public-private interaction. Lastly, Chapter 7 presents the conclusions of the thesis alongside possible policy and managerial implications and suggestions for future research.

2. Theoretical framework

This chapter describes the theoretical framework that has been used in framing the studies and analyzing the results. It begins with an overview of the industrial network approach and its relation to public-private innovation networks. A conceptualization of actor roles in networks is then presented as part of understanding how roles affect changing networks. Lastly, the problem formulation and research questions are presented.

2.1 The Industrial Network Approach

This thesis relies upon the Industrial Network Approach (INA) to provide a fundamental understanding of actors, activities, and resources in business networks and their interplay (Håkansson, 1987). According to the INA, industrial markets are to be considered as networks of numerous connected business relationships in which no actor acts in isolation (Håkansson and Snehota, 1995). Instead, there are continuous interactions and exchanges between organizations by which relationships develop over time based on new and past experiences, new ideas, and expectations of future activities (Ford, 1980; Håkansson *et al.*, 2009).

Based on the INA, industrial networks are built from three basic elements, *activities*, *resources,* and *actors*, also known as the ARA model (Håkansson and Snehota, 1995). *Activities* refer to what actors do, for instance producing, purchasing, selling, processing, or sharing data. *Resources* refer to the means for carrying out activities, such as material, knowledge, staff, vehicles, computers or systems, and data access. These can sometimes be difficult to distinguish, as the value of a resource lies in its use potential (Penrose, 1959). Furthermore, no single actor has all necessary resources, hence actors need to rely on resources provided by other actors (Håkansson and Snehota, 1995). The final element, *actors*, is described by Håkansson and Snehota (1995) as the dimension that goes beyond activities and resources, focusing on the perceptions, knowledge, and capabilities of the nodes. This refers to the bonds and relationships between nodes and how they develop over time. According to Halldorsson *et al.* (2007), the INA is a descriptive theory that can be used to map activities, resources, and actors, and how organizations interact and develop trust and confidence in interorganizational relationships over time.

2.2 Resource interaction and combination

Resources can be either tangible (i.e., equipment, land and natural resources, raw materials, plants, goods, waste products, and by-products) or intangible (i.e., human resources, knowledge, relationships, trust, and reputation;) (Håkansson and Snehota, 1995; Penrose, 1959). These tangible and intangible resources can be combined in different ways to create services that contribute to more efficient or productive activities (Penrose, 1959). Within the INA, the value of a resource lies in its use potential, in other words the potential for the focal firm or another actor within the network to create value from it (Håkansson and Snehota, 1995).

Resource interaction can be defined as "…the processes of combination, recombination, and co-development of resources" (Baraldi *et al.*, 2012, p. 266). Through interaction, organizations can access and relate to activities of other organizations. Combining internal and external resources in this way is central to the development of resources, products, and services. Technical development and innovation require novel resource combinations. Resources are controlled by different actors within a network, whereas innovation is achieved through interactions between actors (Håkansson and Waluszewski, 2007) that lead to long-term value co-creation by identifying valuable combinations of resources (Laage-Hellman *et al.*, 2021). However, the intentions of other organizations regarding certain resource combinations cannot be fully known in advance (Ford *et al.*, 2003).

2.3 Innovation in networks

Developing and introducing new transport solutions is closely linked to innovation. New solutions are conceived in innovation processes that entail new combinations of resources. However, innovation is more than just coming up with new solutions, introducing an old idea into a new context, or combining new or existing resources in new ways—it also includes the integration and commercialization of the new solutions (Van de Ven *et al.*, 1999; West and Bogers, 2014).

However, a core issue regarding innovation is adaptability and how a solution can be integrated with a business operation to create value in a specific context (West and Bogers, 2014). New solutions are not used in isolation and have to connect to existing knowledge, activities, and technical solutions within organizations. A new solution, being a result of resource combination, might need further combination or adaptation to fit with established resources or services. This notion relates to the underlying assumption on resource heterogeneity articulated by Penrose (1959) that the value of a resource depends on how and with what other resources it is combined. Furthermore, resource combining or interaction in innovation is closely connected to the actors within a network, as it is they who conceive, activate, and, foremost, use resources (Cantù *et al.*, 2012). An innovation process can include multiple actors ranging from customers, suppliers, distributors, regulators, and academia. Hence, many different interactions occur simultaneously, which can result in various sources of value. By studying innovation projects, Lind *et al.* (2012) concluded that values can be produced during different stages of projects, and not only as an ultimate objective, as resources and resource combinations can be developed and used throughout.

2.4 Public-private innovation networks

Although INA is commonly used as a theoretical lens in business relationships, it has in recent years proven useful in the context of public-private interaction (Håkansson and Axelsson, 2020; Munksgaard *et al.*, 2017; Nissen *et al.*, 2014; Wagrell and Baraldi, 2019). Interaction between public and private actors is considered complex due to regulatory constraints and procurements (Melander and Arvidsson, 2020), differences in objectives (Munksgaard *et al.*, 2012), and additional bureaucracy (Smith *et al.*, 2019). However, building relationships between public and private actors for specific exchanges and innovation is considered to contribute to new solutions that provide value for both public and private actors. For instance, Melander and Pazirandeh (2019) mention how important it is for firms to expand beyond firm boundaries and include both public and private organizations in multi-actor collaborations for green innovation. Various complex challenges, such as climate change and the need for increased sustainability, depend on public-private interaction for knowledge exchange, resource interaction, and engagement in developing and implementing products, services, or technologies that contribute to social and business value (Munksgaard *et al.*, 2017; Nissen *et al.*, 2014).

The difficulties of interaction in public-private settings are increased as a result of the inherent differences in objectives and value perceptions among the actors involved (Munksgaard *et al.*, 2012). While the objective of public actors is to serve and protect the well-being of citizens, the objectives of private actors are predominantly economic.

While perceptions of value do not necessarily have to be contradictory, this fundamental difference may present challenges when it comes to integrating new solutions into established practices. The public-private innovation context requires a range of actors and "innovative resource combinations, adaptation between existing and new resources as well as co-existence with other, established or newly developed, services" (Andersson and Mattsson, 2018, p. 5). Public actors are constrained by politically determined regulatory frameworks that systematically organize administrations' resources and activities (Håkansson and Axelsson, 2020). Smith *et al.* (2019) highlight laws, regulations, and additional bureaucracy as factors that affect the speed and agility of public actors and act as potential barriers to collaboration and interaction in a public-private context. Hence interaction between these actor groups depends on multiple factors that need to be considered.

As there is little research on the mechanisms of value creation in public-private collaboration for transport innovation (Cooper *et al.*, 2019), INA can be useful to define the activities, resources, and actors involved and hence better understand the interactions and value arising from innovative transport solutions.

2.5 Actor roles in networks

An innovation process can include multiple actors with various roles. Many interactions occur simultaneously, resulting in various sources of value for different actors during different stages of the innovation process (Lind *et al.*, 2012). As new technologies are developed and deployed, new actors may become involved in the network and the roles of existing actors may change. The "role" concept originally appeared within behavioral sciences and can be defined as the dynamic aspect of an actor's position within a network. Linton (1936) defined a role as the behavior adopted by an actor in dyadic interaction processes. Parsons (1951) argued that a position locates an actor in relation to other actors in a network, while a role focuses on what an actor does in relation to this position. Since then, there has been further discussion of roles in networks, including how actors can take on different roles through their interactions and how they change over time (Guercini and Runfola, 2015).

An actor's decisions depend on how it interprets its role and position within a network, which can depend on other actors' expectations or the intentions of a focal actor (Anderson *et al.*, 1998). Abrahamsen, Henneberg, and Naudé (2012) argue that an important task for actors within networks is to continuously make sense of their roles, which reflects how they interpret their network position. Hence, roles are dynamic in nature and can change over time. An actor may change its role and position within the network to better serve its goals and those of the network (Nyström *et al.*, 2014). Olsson, Gadde, and Hulthén (2013) identify roles in the activity and resource dimensions of networks. The roles they identify in the activity dimension are activity specialization and activity coordination, whereas the roles in the resource dimension are resource provisioning and problem solving. Guercini and Runfola (2015) stress the importance of interaction and highlight that roles are formed through interactions between actors. An actor needs to consider what is required from others within a network to create value without neglecting its own goals. Aaboen *et al.* (2016) discuss how roles depend on resources and resource adaptation in networks. Roles may imply that resources need to be connected, recombined, or substituted for the implementation of new solutions.

2.6 Problem discussion and research questions

Developing and implementing new innovative transport solutions to increase sustainability is increasingly dependent on public-private collaboration and interaction (Böhm, 2019; Dowling and Kent, 2015; Lindholm and Blinge, 2014; Smith *et al.*, 2019; Weber *et al.*, 2014). There are often high expectations of these solutions to contribute to sustainability. However, despite this they are rarely implemented on a larger scale (Wiesenthal *et al.*, 2011), indicating that they do not meet all the aspects of sustainability. Therefore, the first research question is:

RQ1: How do different sustainability aspects of a transport solution affect it going from development to implementation?

There is insufficient research on the process of going from development of a new solution that depends on public-private interaction to its implementation and commercialization (Evald *et al.*, 2014). Technology development and innovation happen less and less in isolation and increasingly depend on networks that involve different types of actors (Nieto and Santamaría, 2007). Innovation in a public-private context is characterized by development collaborations in which the actors are dependent on each other for knowledge, engagement, and/or resources (Nissen *et al.*, 2014). However, networks are subject to dynamic processes that change over time together with the roles of the actors in the networks (Guercini and Runfola, 2015). New elements or technologies can also affect networks, where new actors can enter, some can exit, and for others their roles can change (Nyström *et al.*, 2014). In transport innovation, there are currently several disruptive elements, such as digitalization (Pernestål *et al.*, 2021), that will potentially affect the roles of existing actors and engage new ones. Hence, networks of actors are difficult to define. In addition, going from development to implementation of a new solution affects actor roles where adaptability is required (Aaboen *et al.*, 2016). Therefore, the second research question is:

RQ2: How do network and actor role dynamics affect the implementation of innovative transport solutions that depend on public-private interaction?

Public-private interaction is a central part of creating new solutions that contribute to economic and societal value. At the same time, aspects of value need to be considered in a public-private innovation context with regard to what values are created for the respective actors. Different actors can affect the direction of an innovation depending on their individual objectives (Håkansson and Snehota, 1995). As public and private organizations have different drivers or objectives (Munksgaard *et al.*, 2012), they also have different incentives to participate in developing new solutions. These differences may affect how solutions are formed and, hence, be a contributory in transport solutions not achieving the expected sustainability objectives. Therefore, the third research question is:

RQ3: How does the variety of public and private actor perspectives on an innovative transport solution affect implementation?

3. Methodology

This chapter goes into the methodological considerations and chosen methods for the studies that are the basis of this thesis. It starts by presenting the chosen research design, followed by the research process, description of the specific research methods, and concludes with some methodological reflections.

3.1 Research design and process

As previously mentioned, this thesis focuses on the transport solutions MaaS, UCC, and geofencing. These are to be considered as individual cases that have been studied. They have been chosen because they all depend on public-private interaction, are in different phases of development and implementation, and are considered to contribute to sustainability and value creation for multiple actors.

To understand the challenges within networks in going from development to implementation of new transport solutions from a network perspective, a qualitative approach has been used. This approach allows researchers to explore a context from different perspectives (Taylor *et al.*, 2016) and understand it from the participants' point of view (Bell *et al.*, 2019). By studying a smaller number of participants and/or situations, it is possible to better to understand the studied context and the processes, actions, interrelations, and influences within it (Maxwell, 2004). Hence, with a qualitative approach it is possible to observe similarities and differences in the views, objectives, and perspectives of different actors and thus differentiate their interactions and analyze how different mechanisms affect each other in the innovation process.

The scope of this research was partly formed before the research process started in March 2020. While working with transport innovation since 2017 and being involved in projects to develop new transport solutions, foremost in public-private constellations, many questions surrounding the difficulties of implementation were raised. These questions included how to scale up relatively small pilots and demonstrations to integrate them in established processes and routines and how to achieve viable business models. For instance, these questions were raised within the Research and Innovation program for geofencing initiated by the Swedish Transport Administration in early 2019. Similar questions have been raised in various projects and initiatives, such as Smart urban traffic zones (CLOSER, 2022b), Stadsleveransen (Katsela and Browne, 2019), LIMA (Drive Sweden, 2022), NordicWay 2 & 3 (Swedish Transport Administration, 2022), and GeoSence (CLOSER, 2022a), as well as other ongoing initiatives at different levels. This laid the empirical foundation for this research project.

Data collection for the literature review, focusing on the sustainability aspects of MaaS and UCC, and the first interview study focusing on actor roles in the development of geofencing began in 2020 and were finalized during 2021. The focus and design of the second interview study were then formed; data collection began in the summer of 2021 and was finalized in the autumn.

3.2 Research method

This thesis is based on three studies: (1) a literature review of the sustainability of transport solutions in urban environments, (2) an empirical study with interviews focusing on key actors in the development of geofencing and actors' roles and expectations of future roles within the network, and (3) an additional empirical study mainly comprised of interviews with actors in the network with the focus being on values and barriers for the implementation of geofencing. During the process, there have also been opportunities to collect additional data from various sources that complement the literature and interview studies.

3.2.1 Literature review

A literature review is usually conducted in an early phase of a research project to gain a better understanding of existing knowledge of the subject (Bell *et al.*, 2019). This involves not only reading articles in academic journals and recording the theories and opinions of the authors, but also interpreting what has been written and using the ideas to support the researcher's own viewpoint or argument (Bell *et al.*, 2019). The literature review we conducted synthesized the existing body of research regarding sustainability and urban mobility solutions. For this literature review, we wanted to evaluate the transport solutions of Mobility as a Service (MaaS) and Urban Consolidation Centers (UCC) in relation to social, environmental, and economic sustainability. The literature review was conducted using two separate searches, one for "MaaS" and "sustainability" and one for "UCC" and "sustainability", which resulted in a total of 137 articles for the literature review. The process of the literature search is described in Figure 1.

The transport solutions were first analyzed individually according to the framework of social, environmental, and economic sustainability. They were then compared and put into mega-matrices (Miles and Huberman, 1984). These matrices enabled both an analysis of each transport service individually as well as a comparison of the sustainability of MaaS and UCC.

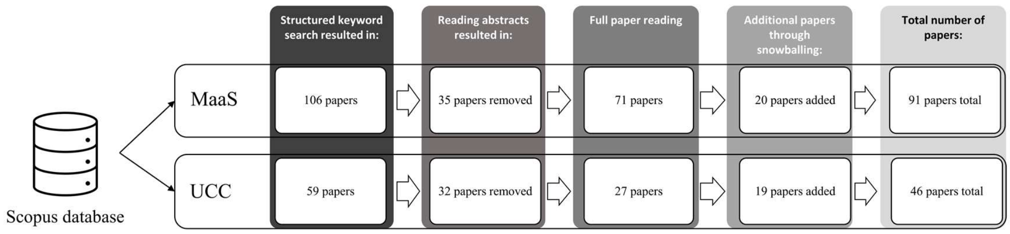

Figure 1. The process of the literature search

3.2.2 Empirical studies

The empirical studies consisted of two separate rounds of semi-structured interviews that focused on geofencing technology in freight transport management. Conducting studies that focused solely on geofencing enabled a better understanding of the actors and links between them, as well as different perspectives on geofencing. Sweden was the starting point, as it has several ongoing initiatives within geofencing that rely upon public-private collaboration. Geofencing has been tested for a number of different applications, such as speed adaptation and zero-emissions zones, in several innovation projects in different cities. Hence Sweden is considered an ideal setting for studying networks, actor roles, and interactions related to geofencing. To narrow the scope of the study, the focus was primarily on freight-related initiatives and applications.

The first round of semi-structured interviews addressed the actors, their roles, and their expectations for future roles in the development and implementation of geofencing. Data collection was initiated in late 2020 and resulted in 18 interviews with 26 unique respondents, shown in Table 1. An interview guide was used that focused on the actors involved in the development of geofencing, drivers for developing geofencing, interactions between actors in the development of geofencing, and the roles of different actors in existing settings and their expectations for roles in future settings. The respondents were sampled from a network of public and private actors participating in freight-related projects including different applications of geofencing and representatives working with strategic planning of freight in cities. Furthermore, the respondents were given the opportunity to name other actors who could be of interest to interview, resulting in a number of extra interviews with more knowledgeable respondents within the organizations or externally. The interview transcripts were coded and analyzed throughout the data collection. Coding was empirically driven with labels related to drivers and motivations; the barriers to development, implementation and participation in geofencing activities; and actors' roles, expectations, and role changes in networks. The data was then structured in tables to map the activities, interactions, and drivers of geofencing development.

The second round of semi-structured interviews was initiated in summer 2021 and resulted in an additional 16 interviews with 18 unique respondents. This round focused more on private actors who currently have little involvement in developing geofencing but will be directly or indirectly affected by its implementation and usage. An interview guide was developed, which included questions about geofencing, such as if an organization uses geofencing and the values and barriers related to the implementation of geofencing in the future. Sampling was conducted, firstly, by identifying geofencing-related actor categories and, secondly, by identifying actor types within each actor category; these are displayed in Table 1. This process was conducted in collaboration with the Swedish Research and Innovation program for geofencing. Data analysis was done by dividing the data into 1st order concepts, 2nd order themes, and aggregate dimensions (Gioia *et al.*, 2013).

Table 1. Type of organizations and participants in the interview studies

	Actor category	**Type of organization**	**Number of interviews**	**Number of respondents**
1st round of interviews	Authorities	Local road authorities	6	7
		National road authorities	2	3
	Geofencing service providers	Vehicle manufacturers	6	11
		Third-party service providers	1	2
		Map service providers	2	2
2nd round of interviews	Transport service providers	Freight operators	3	3
		Haulage depots	1	1
		Freight forwarders	1	1
	Buyers of transport service	Retailers	4	4
		Raw material producers	1	1
	Enclosed or specified areas	Ports	2	2
		Road works	1	1
	Influencing actors	Insurance companies	3	5
		Trade organizations (transport)	1	1

3.2.3 Additional data collection

Additional data was collected throughout the research process through observations and discussions in various meetings, reference groups, seminars, and workshops. Other sources of additional data included various reports and documents issued by projects, institutes, or authorities. The projects, forums, and reports that were most relevant for this thesis are shown in Table 2 alongside the researcher's role in the initiative. Meetings, seminars, and workshops have been documented by personal notes. Although additional data can be useful to conduct meaningful analysis, researchers must be careful of potential biases of the data provider (Bell *et al.*, 2019). In this research, additional data has been used to either assist in forming interview guides or to confirm what respondents have said in interviews, adding to the validity of the primary data source.

Table 2. Additional data collection during the research process

Project/initiative	**Type of initiative**	**Researchers' role**	**Data collection**
Smart urban traffic zones	Innovation project	Part of reference group and participant in project-related workshops	- Notes from reference group meetings regarding challenges in project relating to various geofencing applications - Participated in workshop on business models for various geofencing applications - Notes from project-related seminars and presentations
R&I program geofencing	Swedish collaboration platform for geofencing	Participant	- Notes from various geofencing-related workshops and discussions on different topics, i.e., scaling, business models, standards, and policy
GeoSence	EU research project on geofencing for public authorities	Project participant	- Notes from project discussions on challenges and opportunities with geofencing for local road authorities
DigITS	Initiative by Swedish Transport Administration on improving implementation of Intelligent Transport System services	Part of evaluation group	- Notes from meetings discussing challenges for authorities to implement ITS, for instance, geofencing
Gothenburg freight network	Local freight network	Organizer and participant	- Listen to various presentations and discussions on urban freight transport challenges and solutions, for instance use of UCC
Other	Reports and conferences	Observer	- Notes from POLIS conference on urban mobility, 2021, in Gothenburg (presentations on UCC, MaaS, and geofencing/ITS) - Memorandum to the Swedish Department of Infrastructure—*The issue of responsibility for automated driving and new rules in order to promote increased use of geofencing*

3.3 Reflections on methodology

It has been a challenge to identify specific phenomena to study, as the development and implementation of new transport solutions and technologies in public-private contexts include many different aspects. Hence, the research process has entailed the constant development of empirical scope and theory, a process referred to as systematic combining (Dubois and Gadde, 2002). This means that the researcher goes "back and forth" between research activates and between empirical observations and theory. Being introduced to the Industrial Network Approach (Håkansson and Snehota, 1995) early in the research process, it was possible to better distinguish how to approach the empirical context. Initial data processing made it possible to identify theoretical frameworks that could help in analyzing the material and whether additional analytical tools were needed. For instance, the INA helped in forming initial thoughts and in the planning of the first empirical study, intended to provide an understanding of the networks and interactions involved in developing and implementing geofencing. However, it was during initial data collection that that the difficulty of distinguishing actor roles in the development and implementation of geofencing arose as a prominent issue. Hence, theory on actor roles took a more central role in the theoretical framework. It was not sufficient to look only at interactions to understand the challenges in going from development to implementation of innovative transport solutions; roles needed more attention. It became increasingly clear that difficulty in distinguishing roles can also affect the necessary interactions between actors. Hence, a new dimension of the research problem was discovered, affecting both the perception of the empirical context and the theory that can help interpret that context best. Additional data collected throughout the research process has also contributed to a better understanding of the empirical context and the potential theoretical lenses that may be needed to better understand that context. This research process has not taken a straight path with the research phenomena and choice of theoretical framework and how to use them being set in stone from early on; instead, our understanding of both the empirical world and how to analyze it has evolved during the process, resulting in a more rich understanding of the challenges of going from development to implementation of innovative transport solutions as a whole.

4. Summary of appended papers

This chapter presents a summary of the three papers that contribute to this thesis. The first and second papers have already been published, while the third has been presented at the IMP conference in Florence, August 2022, and will be further developed. Table 3 provides an overview of the three papers.

Table 3. Overview of the appended papers

	Paper 1 *– How sustainable are urban transport services? A comparison of MaaS and UCC* *Published article*	***Paper 2*** *– Actor roles and public-private interaction in transitioning networks: The case of geofencing for urban freight transport in Sweden* *Published article*	***Paper 3*** *– Multiple perspectives on the values of a resource combination—The case of geofencing in freight transport* *Conference paper/work in progress*
Purpose	To review the social, environmental, and economic sustainability of the urban transport services MaaS and UCC and discuss how sustainable the business models are in practice.	To investigate actor roles and public-private interactions in networks. Role dynamics are explored in two settings: the current innovation network and the future implementation network to which actors are transitioning.	To contribute to the understanding of actors' perceptions of resource combinations and how values resulting from interaction are based on the multiple perspectives of the public and private actors involved
Research design	Multiple case study	Qualitative case study	Qualitative case study
Data collection	Literature review	Interviews, observations, reports	Interviews, observations, reports
Findings	Transport solutions often fail to fulfill promises of social and environmental sustainability. Furthermore, the economic viability of the business models is yet to be proven.	Roles in the development and implementation of geofencing are identified where actors may take on one or several roles. Furthermore, the expectations of other actors' roles in the network moving toward implementation are identified, and how these expectations may affect how the technology will be implemented is studied.	Different sources of value require varying degrees of external interaction, and the variety of use cases for a resource poses challenges for its implementation. The wider range of value that can be created through the different uses of a resource, the more complex the interactions required to develop the resource features to satisfy the variety of actors involved.

4.1 Paper 1: How sustainable are urban transport services? A comparison of MaaS and UCC

The purpose of Paper 1 is to review the social, environmental, and economic sustainability of the urban transport services Mobility-as-a-Service (MaaS) and Urban Consolidation Centers (UCC) and discuss how sustainable the business models are in practice. There are fundamental sustainability issues that need to be addressed within urban transport and call for technological and behavioral changes (Pei *et al.*, 2010). New transport services, such as MaaS and UCC, aim to provide sustainable transport solutions that offer reduced emissions and safer urban environments. However, these are often difficult to implement and combine with viable business models due to the variety of actors involved.

The literature review showed that even though both MaaS and UCC promise significant social and environmental sustainability benefits, they have yet to live up to these promises. Whether MaaS will achieve its potential social benefits is still an open question, and UCC will only contribute to social and environmental sustainability if sufficient transport volumes can be obtained, which has so far proven difficult. Furthermore, although both transport services can be economically viable, they have struggled to prove this long term and are often dependent on public subsidies. The paper also discusses how Information and Communication Technology (ICT) can be an enabler for these transport solutions by facilitating viable business models. Furthermore, behavioral change plays a central role, as users of transport services need to accept the solutions to guarantee their economic viability.

The paper contributes to the understanding of the opportunities and challenges of novel transport solutions, especially in the transition from small-scale testing and pilots to large-scale implementation. These challenges include coordinating large numbers of actors, establishing viable business models that rely upon behavioral changes, policy adaptation, and having the right technical tools for support.

4.2 Paper 2: Actor roles and public-private interaction in transitioning networks: The case of geofencing for urban freight transport in Sweden

The purpose of Paper 2 was to investigate actor roles and public-private interactions in networks. Role dynamics are explored in two settings: the current innovation network and the future implementation network to which actors are transitioning. The background to the paper was the recognition of the challenges of collaboration and coordination among public and private actors in going from the development of a transport solution to its large-scale implementation. The paper is based on a study on geofencing, in which there is a reliance upon public-private interaction and the roles for various actors in future implementation are unclear. Interviews were used as the primary data collection source.

The paper identifies the actors involved, their roles, interactions, motivations, and expectations for their roles in future implementation of geofencing. The analysis indicates that the actors are dependent on each other during the development phase and that their roles are fairly clear within the projects being conducted. However, there is some vagueness around the expectations of the other actors within the network when envisioning large-scale implementation of the technology. The network is expected to change, with some actors from the development stage exiting the network and new ones entering. Some actors are expected to take on new roles and others are expected to take on multiple roles. There is ambiguity around the expectations over future actor roles, which is increased as a result of the various different drivers for geofencing implementation, derived from the inherent differences between public and private actors.

The paper identifies three types of role developments going from development to expected implementation: (1) *business-as-usual*, (2) *path-breaking*, and (3) *incremental*. These role developments depend on how the network develops, how actors perceive their roles, and the expectations of other actors. Despite the uncertainties, the ongoing small-scale projects help actors to identify and distinguish their roles. However, a challenge that is emphasized is that the departments and divisions involved in the development phase within organizations are not the same as those that will be involved in the day-to-day operation of geofencing.

Overall, the paper contributes to the understanding of network and role dynamics in the development of a new transport solution that depends on multiple actors and public-private interaction. Although ongoing small-scale projects assist in shaping networks, and the expectations for future networks, there are still challenges in bridging the differences in role expectations between actors, which is exacerbated by the involvement of both public and private actors.

4.3 Paper 3: Multiple perspectives on the values of a resource combination—The case of geofencing in freight transport

The purpose of Paper 3 is to contribute to the understanding of actors' perceptions of resource combinations and how values created through interaction is based on the different perspectives of the public and private actors involved. The background to the paper is the challenges with resource interaction in networks consisting of public and private actors due to inherent differences in the objectives and perception of value between them (Munksgaard *et al.*, 2012). The paper is based on a qualitative study focused on geofencing solutions as a resource with interviews as primary data collection source.

The results show that there is a wide range of potential use cases for the technology, indicating diversity in the way geofencing is perceived as resource. Furthermore, there are many different sources of value on different aggregated levels, including the firm, network, and societal levels. Firm level value often implies less interaction between actors, as it tends to be based on more local solutions, while societal value tends to require more complex interactions between multiple actors. While the perceptions of value among actors are not always contradictory, the diversity of value perceptions may lead to challenges in the implementation of the technology, as actors perceive geofencing as a resource in relation to other resources and how it is used. The paper suggests a proposition for further scrutiny: *The wider the range of value that can be created through the different uses of a resource, the more complex the interactions required to develop the resource to satisfy the variety of actors become.* Overall, the paper helps in understanding various perceptions of the value of a resource in a public-private context and how these perspectives define the resource and its potential use.

5. Results

This chapter presents the results of the thesis by answering the three research questions previously stated. Figure 2 shows how the papers have contributed to addressing the research questions.

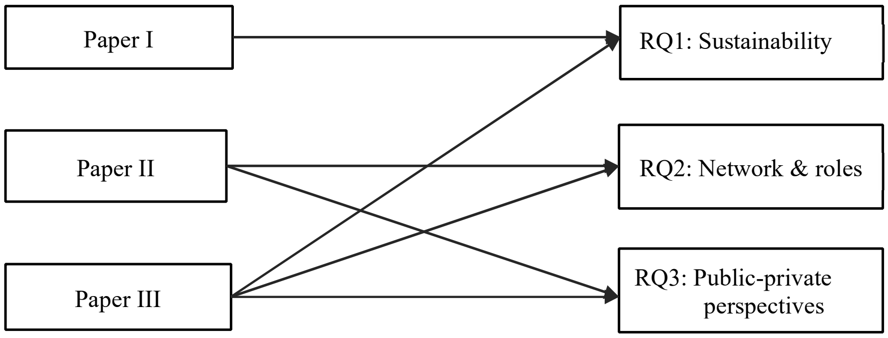

Figure 2. The appended papers and connections to the research questions

5.1 RQ1: How do different sustainability aspects of a transport solution affect it going from development to implementation?

The main contributions to this research question can be found in Paper I and Paper III. Fundamental to all the transport solutions studied is that they include a sustainability aspect, which can be social, environmental, and/or economic. Paper I and Paper III show how MaaS, UCC, and geofencing aim to contribute to sustainability as well as their negative impacts or barriers to increasing sustainability, as displayed in Table 4.

Although MaaS, UCC, and geofencing aim to contribute to increased social, environmental, and economic sustainability, it has yet to be realized in practice. Either there are potential downsides with the transport solution, the number of users needed to increase sustainability is difficult to attain, or the transport solution has too many potential organizational and economic barriers to efficiently achieve the desired sustainability benefits. All the transport solutions studied have struggled to demonstrate long-term economic viability, and most initiatives depend on government funding or subsidies to operate. Limited sustainability benefits and difficulties in measuring and showing the advantages of the transport solutions make it increasingly difficult for actors to justify support for implementation when other measures or solutions can be seen as better investments.

Table 4. Overview of sustainability aspects of studied transport solutions

		MaaS	***UCC***	***Geofencing***
Social sustainability	Positive	+ Affordable transport + Creates a more accessible urban environment by combining multiple transport modes + Enables healthier choices, such as cycling and walking	+ Reduced use of HGVs in urban environments + Reduced health issues from freight transport, such as pollution and traffic accidents + Better working environments for transport operators	+ Makes the city environment quieter, cleaner, safer, and more accessible + Reduces noise and speed of traffic, and improves traffic safety, which leads to a better psychosocial environment + Better working conditions for drivers
	Negative	- Doubts over whether healthier options will be used - Tailor-made transport results in less walking and cycling - Exclusion of certain groups of people		- No real measured effects (tests are still small in scale) - Risk of excluding some group of people (only wealthy people/ organizations can afford the solution) - The problems it addresses are relatively small - Disturbing for drivers if additional equipment is needed in vehicles - Risk of additional surveillance - Risk that drivers rely too much on technology
Environmental sustainability	Positive	+ Promises to deliver environmentally sustainable transport services to urban areas + Reduced gas emissions + Reduced congestion + Potential to reduce the number of cars in urban areas	+ Evidence of GHG emissions reductions of 25–80% + Increased load factor of last mile deliveries + Reduced congestion in dense urban areas	+ Incentive for electrification + Emissions reductions, resulting in better air quality + Enforcing environmental zones and dynamic environmental zones + More sustainable speed (lower speed results in lower emissions) + Enables night-time deliveries by requiring the use of electric power and lower speeds
	Negative	- May have less impact on environmental sustainability than first believed - Limited evidence of improved environmental sustainability	- Needs high volumes for substantial effects	- Little incentive for OEMs to develop geofence service to enable applications for environmental sustainability - Other measures can have more effect and be easier to implement - Effects are difficult to measure
Economic sustainability	Positive	+ Potential to be economically viable	+ Potential to be economically viable	+ Reduced fuel consumption + Less damage to vehicles and infrastructure + More efficient and better traffic management + Less need for physical barriers + Better monitoring and tracking of vehicles and goods + Good for branding
	Negative	- Yet to prove economic sustainability - Questions over access to subsidized public transport for MaaS - Potential to cannibalize existing public transport	- Few cases in which substantial volumes have been achieved for financial viability - Often relies on subsidies - Relies on creativity and entrepreneurship - Often relies on supportive measures, such as policies or regulations	- Other solutions or measures can be cheaper to implement - Uncertainty regarding business models - Unclear if adds real value - Contracts are often short, resulting in fewer opportunities for large investments

To conclude, although the studied transport solutions are intended to contribute to increased sustainability, it is not clear that they achieve this. There are challenges in scaling up the solutions, which implies the involvement of more actors and more interactions between them. Hence, there is a need to further look at the network perspectives and the implications for implementing sustainable transport solutions.

5.2 RQ2: How do network and actor role dynamics affect the implementation of innovative transport solutions that depend on public-private interaction?

The second research question goes into the specific network-related challenges of going from development to the implementation and scale-up of new transport solutions. This question relates to how networks are composed and how roles and role dynamics in these networks affect the challenges of going from development to implementation of a transport solution. The main contributions to this question can be found in Papers II and III.

Firstly, the networks for implementing the studied transport solutions are not always easy to define. For geofencing, which can have several different applications, configurations can differ depending on the mode of traffic, implementation area, and application. For UCC, there can be different actors involved depending on the area covered and type of customers served.

Secondly, it is not always the same actors who are involved in the development of a transport solution as in its integration and full-scale operation. In Paper II, it is shown that although geofencing is in its infancy, the actors expected to be part of its large-scale implementation are different from those currently involved in its development. This can be observed on several organizational levels and have various implications. For geofencing, it is expected the people or divisions involved in the development of the transport solution within an organization will be different to those who will later be involved in the operation, functionality, or use of the transport solution. The implications are that functionalities developed in projects by people with certain skills and objectives may later be difficult to implement, because other people in the organization do not have the right skill sets or tools, or because the particular transport solution cannot be combined with other processes or routines.

Thirdly, there are challenges in understanding roles and role dynamics in networks going from development to implementation. Paper II, which focuses on geofencing, studies the changes in actor roles when developing and implementing a transport solution that depends on public-private interaction. As mentioned above, the network of actors changes going from development to implementation. Actors can exit and enter the network, and the roles of actors within the network can change. In the study, three general role development types could be identified when going from development to implementation, *business as usual*, *path-breaking,* and *incremental change*. *Business as usual* refers to cases in which there is an expectation of limited or no change in actors' respective roles. *Path-breaking* refers to cases in which actors need to make radical changes in their roles, either regarding the activities they perform or how they interact with other actors in the network. This also includes actors who either enter or exit the network going from development to implementation. Lastly, there can be *incremental change* to roles, meaning that actors adapt their roles in response to new knowledge or changes to the roles of other actors in the network.

The roles an actor takes on are heavily dependent on resource interactions and vice versa. Paper II indicates that actors involved in developing new transport solutions adopt their roles in relation to other actors in the network, primarily in relation to developments in technology, policy, and the market. Paper III shows that more complex solutions require the involvement of more actors and more interactions, which complicates development. This makes the use and value of a solution more uncertain, creating more vague expectations of future roles of actors. This is exacerbated by the involvement of both public and private actors due to the differences in their objectives. This uncertainty around expectations of future roles may create difficulties in adapting to new roles with regard to technology integration and use. Furthermore, Paper II indicates that actors can take on several different roles, both as enablers and users of a solution.

For geofencing, the uncertainties are even greater due to the many possible applications of the technology in various transport solutions. In developing different features of geofencing, the involved actors, such as vehicle and/or fleet owners, transport authorities, and vehicle manufacturers, may take on different roles in establishing and operating the geofencing solution. This, in turn, impacts the features of the geofence solution and thus also the value that can be captured by different actors and society at large.

5.3 RQ3: How does the variety of public and private actor perspectives on an innovative transport solution affect implementation?

The main contributions to this research question can be found in Paper III and to some extent in Paper II, both of which focus on geofencing.

Paper III explores the different sources of value from geofencing as a resource or as part of a combination of resources. Geofencing can provide different value for different actors and applications. These can be identified on the firm, network, and/or societal level. For instance, depending on the application, geofencing can create value for firms by improving the work environment, simplifying administrative tasks, reducing costs, and increasing performance. On the network level, geofencing can provide value for multiple actors by reducing costs, improving safety, improving compliance with agreements, and assisting them in reaching set sustainability goals. On the societal level, geofencing can, depending on the application, create value for citizens through increased traffic safety, environmental benefits, and improving urban environments and planning. Hence, geofencing as a resource can provide value for a number of actors. However, there are often different views on how geofencing should be used and integrated or combined with other resources. Furthermore, the study indicates that value is often easier to capture at the firm level as it may only require simple solutions that can be implemented at local sites, such as warehouses or harbors. Achieving network- or societal-level value requires the involvement of more actors, such as authorities responsible for public roads. This adds an additional dimension in the form of public and private actors' inherent differences in objectives and perspectives of value. Although perceptions of value are not necessarily contradictory, it seems that these differences may entail challenges when it comes to integrating new solutions into established practices and resource constellations. This is because the resource, in this case geofencing, can be considered to offer a wide range of potential sources of value due to its broad range of potential uses and the variety of actors involved in its implementation, which requires more complex interactions to satisfy all involved actors. Hence, the greater the range of potential sources of value that a specific solution may present, the more difficult it is to integrate into established practices and routines among involved actors.

Paper III also discusses how geofencing mainly concerns two types of resources, namely technical resources and organizational resources. Technical resources include the various tools and infrastructure that enable that distribution and activization of a geofence solution, such as digital infrastructure and technical equipment in vehicles. Organizational resources relate to how geofences are used, such as to control, inform, or monitor vehicles in designated zones. This also relates to the different actor roles that enable a geofence solution, which are discussed in Paper II. It is shown that there are many uncertainties relating to the functionality of geofencing, with regard to data sharing, responsibilities among actors, and monetary exchange. These all affect how actors interact and how geofencing can be integrated into established practices and routines, and how it can be combined with other resources, for instance in relation to electric vehicles, other transport solutions or data sources.

6. Discussion

This chapter discusses the study findings in relation to previous research and expands on the results to contribute to current understanding of the challenges of implementing innovative transport solutions that depend on interaction between public and private actors. Based on the results three challenges have been identified: (1) the challenge of achieving the sustainability objectives of innovative transport solutions, (2) the challenge of understanding networks and actor roles in innovative transport solutions, and (3) the challenges with resource interaction and combination for innovative transport solutions. The discussion will discuss these three challenges in more detail.

6.1 The challenge of achieving the sustainability objectives of innovative transport solutions

Developing and implementing new transport solutions that depend on public-private interaction is considered essential to reach set sustainability goals in relation to emissions, traffic safety, and accessibility (Pei *et al.*, 2010). Although many different solutions that rely on behavioral changes and new technology have been developed and tested, few have reached a stage of implementation that provides significant sustainability benefits. The results in this thesis support previous research that indicates difficulties in reaching intended sustainability objectives with the new transport solutions. In some cases, it is difficult to attain the necessary volumes to achieve the desired benefits; some solutions present trade-offs between environmental, social, and economic sustainability objectives; and in some cases it is difficult to measure actual sustainability benefits or compare the solution to other solutions or measures that may provide similar or better results. Research conducted into the potential sustainability benefits of these transport solutions estimates emissions reductions ranging from 25 to 80% for UCC (Allen *et al.*, 2012; Clausen *et al.*, 2016; Dupas *et al.*, 2020; Kin *et al.*, 2018; Lin *et al.*, 2016; Papoutsis *et al.*, 2018; Van Duin *et al.*, 2016; van Heeswijk *et al.*, 2019); these estimates should be considered accurate as long as the solution is implemented as intended and with sufficient volumes. However, how to reach the sufficient volumes for substantial sustainability benefits is a question that is perhaps not always considered. This raises questions about legislation (Smith *et al.*, 2019), business models (Li and Voege, 2017), and user resistance (Tsakalidis *et al.*, 2020).

It has previously been stated that public and private actors have inherent differences in objectives and value perception (Munksgaard *et al.*, 2012). However, Paper III, which focuses on geofencing, shows that perceptions of value are not necessarily contradictory but may lead to challenges for implementation since the more potential sources of value a transport solution can provide, the more difficult it is to define the features of the solution. Paper III shows that the value of geofencing in particular can be identified across firm, network, and societal levels, similarly for MaaS and UCC in Paper I. Value created across these different levels implies an increased number of interactions are required to enable the service as more actors are involved. Local solutions, which only provide value for a single firm, are easier to implement as fewer interactions are needed and only the value propositions of a small number of actors need to be considered. Creating solutions for larger areas that include both public and private actors result in more interactions and more complex value streams but can, if successfully implemented, result in greater value capture for surrounding actors and sustainability benefits for society as a whole.

This leads to a paradox that characterizes the challenge of achieving the desired sustainability benefits of the developed transport solutions: *the use of novel transport solutions needs be scaled up to achieve the desired sustainability effects, but scaling up in some cases implies more obscure values for the involved actors, which reduces their willingness to make necessary investments to scale up the solution.* This means that even though the transport solutions have high potential to increase sustainability, it becomes increasingly difficult to reach set goals the more a solution depends on public-private interaction. Furthermore, some actors involved in the development of a transport solution operate in national or sometimes even global arenas, hence they have to consider the scalability of the solution. Other actors involved, such as public road authorities, have more local objectives, meaning a developed solution may have been adapted to a local context that hinders its widespread implementation. Lastly, small-scale projects in many cases seem to mainly target one or two sustainability objectives in relation to the triple bottom line, while scaling a solution that depends on public-private interaction requires targeting all three aspects of sustainability: economic, environmental, and social.

6.2 The challenge with understanding networks and actor roles in innovative transport solutions

Previous research on the challenges of going from the development to the implementation of new transport solutions has not looked at public-private network aspects and role dynamics among actors to any significant extent, despite the fact that different actors can influence development and that collaboration and dialogue among actors is considered essential for achieving set sustainability goals (Melander *et al.*, 2019). As there are many actors involved in developing the different transport solutions, there are many different perspectives to consider. As the innovation process is tightly linked to the actors within a network, since it is they who develop and use the new solutions (Cantù *et al.*, 2012), it is essential to consider how networks (or lack thereof) and the actors within them interact and develop over time.

All three studied transport solutions, UCC, MaaS, and geofencing, consist of complex networks of diverse actors that need to collaborate to achieve the desired sustainability objectives. All three transport solutions are context dependent, meaning that there can be different applications for the solutions and the group of actors involved varies depending on the geographical location, type of solution, or context. Successfully implementing a MaaS service, UCC, or geofencing application in one country, city, or area does not mean that it necessarily can be copied and implemented somewhere else. For this reason, it is difficult to define the networks of the studied transport solutions. Smith and Laage-Hellman (1992) state that it is usually difficult to determine the boundaries of networks, as the various actors within them can have indefinite numbers of connections that affect their actions. However, for transport solutions that involve both public and private actors, it can be argued that the difficulty of determining the boundaries of networks is even greater, as interaction occurs on several different levels. For instance, Karlsson *et al.* (2020) point out how the development and implementation of MaaS involves interactions on the micro, meso, and macro level. The macro level consists of national government, the meso level of regional and local government and public and private service providers, and the micro level of citizens, customers, and users. Similar results can be seen in Paper II and Paper III, which show that there are a range of actors on different levels involved in the development of geofencing, ranging from EU legislators to local service providers. Furthermore, Paper II also indicates that the development and implementation of geofencing not only has implications on these different levels but also within organizations, as different departments may be involved in the development and implementation settings. This further emphasizes the difficulties of defining networks.

To further add to the challenge of understanding the network, it can be argued that there are several domains for developing and implementing transport solutions, which all involve different constellations of actors. This notion is similar to that of Wandel, Ruijgrok, and Nemoto (1992), who state that a transport system consists of several sub-systems or layers, namely the supply chain, transport, and infrastructure layers. Similarly, Geels (2012) mentions how technologies develop in an interplay of different developments and in relation to multiple domains, which all affect the ability of a technology to become a part of established systems. Although UCC, MaaS, and geofencing are individual solutions, they are dependent on actors involved in, for instance, infrastructure development (both physical and digital) and vehicle development. Other domains with other constellations of actors that have not been identified in this research could also be of relevance and affect the development and implementation of a transport solution. The relationships between implications that occur between levels and domains and within organizations when going from the development to the implementation of a transport solution are displayed in Figure 3. For instance, within the development of a transport solution there can be interdependencies across different levels that enable the solution to go from development to implementation. These levels can have different implications, for instance, on the micro level there are intraorganizational implications and on the meso level there are implications for actor roles. The development of a transport solution also needs to adhere to overarching regulations and standards on national or international levels (meso level). There is a constant exchange of activities between these different levels to which actors need to adhere. Furthermore, developing a transport solution may require the development of a vehicle or new kinds of digital or physical infrastructure, leading to possible implications between different domains regarding the specific needs and actors involved. Each domain has implications between the micro, meso, and macro levels, as well as intraorganizational implications and implications for actor roles in the development and implementation of new solutions or technologies. For instance, a solution developed in the domain of physical infrastructure needs to adapt not only to its context regarding the micro, meso and macro levels, but also to for instance how vehicles are developed, how technologies enabled by digital infrastructure are developed, and how potential transport solutions that may use the physical infrastructure are developed.

The challenges of defining networks, and because the development and implementation of the various transport solutions seem to depend on multi-level and intraorganizational implications between different domains, it seems that the more complex the network structures, the more difficult it is to go from development to implementation. This relates to the discussion by Browne, Dubois and Hulthén (2022) regarding the complexity of the freight transportation system and how loose couplings between different layers in the system implies difficulties in determine which actors that needs to interact and which actor that needs to act to achieve a specific outcome.

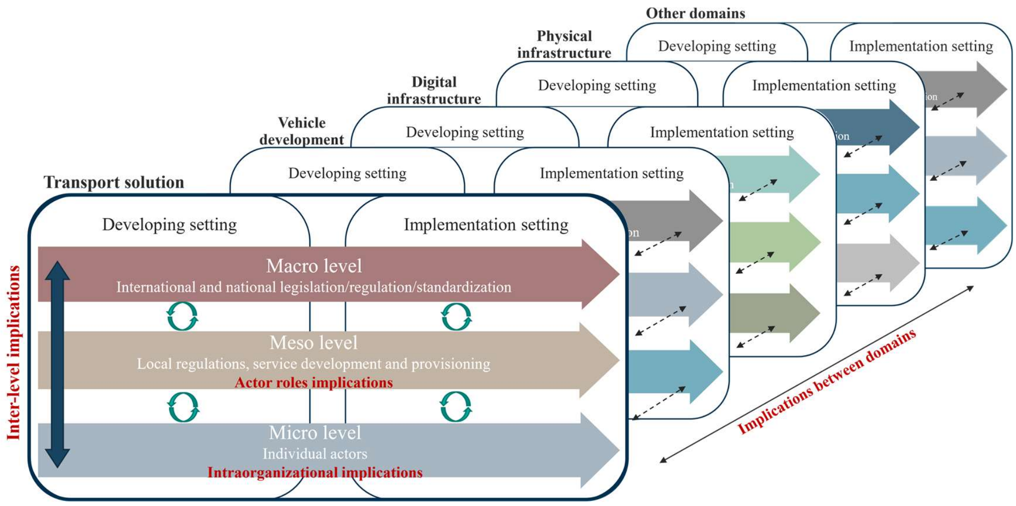

Figure 3. The relationships between implications that occur within organization, between different organizational levels and different domains in going from development to implementation of a transport solution

The networks also relate to the role dynamics of actors. For instance, Karlsson *et al.* (2020) mention how actors will need to take on new roles in the development and implementation of MaaS. Similar results can be found for geofencing in Paper II, where uncertainties over role developments are considered to contribute to the challenges of going from the development to the implementation of the technology. Similar to other studies (e.g., Guercini *et al.*, 2020; Mattsson and Andersson, 2019), Paper II shows that actors, especially public actors, can take on several roles in the development and implementation of geofencing. Furthermore, there is no consensus on what role public actors will have in the future implementation setting of geofencing. The uncertainty over the different roles of actors in a future implementation setting may affect how actors position themselves in the current development setting. As actors continuously need to interpret and make sense of their roles and positions within a network (Abrahamsen *et al.*, 2012), in relation to their own and others' expectations of that role (Anderson *et al.*, 1998), there is a need to make sense of the network and actors in it. The issue here, as discussed previously, is that networks are difficult to define. The difficulty in defining networks of actors could potentially increase the difficulty of going from development to implementation, as it is more challenging for an actor to define its role and those of other actors.

6.3 The challenges with resource interaction and combination for innovative transport solutions

All the studied transport solutions depend on resource interaction and combination, for instance combining and exchanging data to enable certain applications and services. Initially, while developing a transport solution, knowledge exchange is critical to gaining an understanding of how the solution will be applied. Geofencing, for instance, can be applied in various ways to achieve certain goals for different individual actors. How it is used and combined with other resources, such as trucks and traffic management systems, depends on the intentions of the actors. Cantù *et al.* (2012) argue that actors need to see the purpose of a combination of resources to fulfill an objective or goal. Each actor will thus interpret a resource combination based on its network position to see its value in relation to its activities, other resources, and goals. This notion adds to the challenge of implementing geofencing to create a network or societal value, as it can provide many different potential sources of value for different actors, both public and private. Although, as previously stated, these values are not necessarily contradictory, they challenge the implementation of geofencing, as the more sources of value that can be created, the more actors are involved, and the more interactions are needed. This implies that more local, and in some senses simpler, solutions, such as geofencing in closed environments, are easier to implement than geofencing in larger areas, such as public infrastructure, as more interactions and resource combinations are needed. Hence, implementing and scaling up the use of transport solutions that create value for a broad set of actors becomes more difficult. However, to increase the use of and extract value from a new technology or solution, and to achieve sustainability objectives, it must be implemented in a larger context and with larger volumes, as discussed in section 6.1. Currently, the studied transport solutions are being tested in smaller local contexts, where the sustainability benefits are reduced but fewer actors need to be involved, hence, fewer interactions and easier implementation. Scaling up the solutions results in more complex networks of actors and requires the solutions to be placed within a larger context regarding surrounding resources and influencing factors, for instance, trends, markets, and city planning. To scale up transport solutions that depend on public-private interaction not only requires that they interact with existing knowledge, activities, and technical solutions within organizations, but also that they connect to larger contexts that are more difficult to manage. Furthermore, the intentions of other actors regarding resource combinations cannot be fully known in advance (Ford *et al.*, 2003). This implies that the stated intentions of actors when developing a transport solution will not necessarily reflect its implementation. This is due to several factors, some of which have previously been discussed, such as intraorganizational implications and uncertainties over resource provision and role dynamics.

7. Concluding remarks

This chapter returns to the aim of the thesis, which is to contribute to the understanding of challenges with implementing innovative transport solutions that depend on interactions between public and private actors. Furthermore, it presents some policy implications and suggestions for future research.

7.1 Conclusions

The thesis provides deeper insight into three specific challenges with going from the development to the implementation of new transport solutions that depend on public and private interaction. Firstly, there is the challenge of achieving the desired sustainability goals. Either there are negative trade-offs, a lack of volume, or difficulty in measuring actual sustainability benefits. The sustainability potential of MaaS, UCC, and geofencing lies in scaling up the usage of the solutions, which is difficult due to the large numbers of interactions within complex networks. Secondly, there are challenges in defining the networks of actors, as the solutions are simultaneously dependent on the context in which they are developed and implemented as well as external aspects, such as policy development and infrastructure planning. External aspects affecting the development of the transport solutions occur on different levels, from individual departments within firms to international agencies. Furthermore, there are several interconnected parts, or domains, of the transport system that develop simultaneously and may affect one another. Within each domain there are a variety of actors that interact, and developments within one domain affect developments in other domains. Actors, both public and private, can be part of several different domains and have to make sense of their roles in each constellation of networks. The difficulty for actors of coordinating activities between different levels and domains, and internally within organizations, affects the process of implementing innovative transport solutions. Thirdly, the studies indicate that the more uses and potential values a transport solution has, the more difficult it may be to implement. This is because the interactions needed to develop the resource features to satisfy the variety of actors involved become more complex. To extract greater value and contribute to increased sustainability, both public and private actors are involved, which increases the number of interactions in the network and ways a solution needs to be combined with existing resources within each organization.

This research contributes to the understanding of the challenges with implementing innovative transport solutions that depend on interactions between public and private actors. By better understanding the dynamics of transport solution networks, the various roles actors may take on, and the different perspectives on transport solutions, this research builds on the existing knowledge of transport innovation research.

7.2 Policy and managerial implications

Several policy and managerial implications can be identified. Firstly, it seems, in several cases, that there are difficulties measuring and showing actual sustainability benefits for the studied transport solutions. The expected sustainability objectives of a transport solution are calculated using small-scale tests and pilots. However, in several cases, the expected sustainability gains exceeded the results due to the challenges of scaling up a solution. Hence, there may be a need for better assessment tools or indicators that consider the challenges of increasing use.

Secondly, there are challenges in transferring knowledge within and among organizations involved in developing and implementing transport solutions. The people involved and how the solutions operate in pilot projects often differ from when the solution is implemented. There is a need to involve people who work in procurement in the development stage to set specifications for and identify potential problems with a solution. Another consideration is how international or global companies involved in the development of innovative transport solutions think about the scaling up of a solution. Often a solution is developed in a local setting, but to achieve sustainability objectives, its use needs to be increased. Managers in global or international companies could therefore include employees from different geographical locations to ensure that solutions are more easily adoptable in the settings of other cities or countries.

Thirdly, different service providers involved in developing a solution may not be the ones who later win public procurement projects. This may lead to further reluctance from service providers to become involved in some projects and risks knowledge being lost. New types of procurements procedures could therefore be of interest, for instance, “innovative public procurements” in which public actors invest in solutions that need to be developed to achieve a certain outcome instead of investing in off-the-shelf services and products (Edquist and Zabala-Iturriagagoitia, 2012).

Fourthly, there is the challenge of available resources and competence, mainly within public organizations. There is always a trade-off between sustaining everyday functions and operations within the public sector and investing resources in the development of new technology and solutions. Lastly, there are implications for regulations, particularly their implementation. As policymakers tend to follow rather than lead public opinion (Geels, 2012), some of the regulations required for implementing and scaling up transport solutions to allow them to achieve their sustainability objectives are not implemented. Ultimately, unless sustainability goals are prioritized, the implementation of new transport solutions may be politically impossible.

7.3 Future research

There are several potential areas for further research. Firstly, it would be beneficial to look more deeply into the specific solutions that have been studied. For instance, even though this thesis includes a number of in-depth studies on geofencing, it is still possible to focus more narrowly on specific use cases to analyze the specific actors and resource interactions involved. Secondly, transport solutions have mainly been studied in isolation in this thesis. More research to better understand the networks and resource interactions that occur when different solutions or technologies are combined would be of interest, for instance, how geofencing could be an enabler for UCC. As networks and resource interactions become more complex, they could provide mutual benefits. This could also be relevant to technologies not addressed in this thesis, for instance electrification. Furthermore, it would be beneficial to look in more detail at how actors relate to and position themselves in relation to the inter-domain contexts discussed in section 6.2. As the transport system consists of many different components, such as physical infrastructure, digital infrastructure, and transport operations, with solutions developed and implemented in relation to each other, more research is needed to better understand these relationships.

Fourthly, it could be of interest to look into the individual character traits more that ensure ideas and initiatives are nourished. For UCC, in several cases, it has been discussed that the viability of schemes depends on the entrepreneurship and determination of a few individuals. The impact that individual attitudes have on the success of going from development and small-scale testing to implementation would also be of interest.

Lastly, all the studied transport solutions are to a large degree context dependent, meaning that they are developed and tested in individual cities or locations. It is inevitable that some aspects of the transport solutions will need to be adapted to local settings, but for scalability it is also important to understand which aspects can be transferred to other locations. Therefore, there is a need to better understand the aspects of a transport solution that are context dependent and the aspects that are, or need to be, transferable or interoperable. This could provide more insights into the specific roles of some actors in the transport system that are currently unclear or shifting. As many transport operators operate in multiple cities, regions, and countries, some solutions, at least those that depend on ICT, need to function similarly in these locations.

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