UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR TÉCNICO

Mobility as a Service: A tool for steering mobility and fostering equitable transport worldwide

Mauricio José Orozco Fontalvo

Supervisor: Doctor Filipe Manuel Mercier Vilaça e Moura

Co-Supervisor: Doctor Óscar Oviedo-Trespalacios

Thesis approved in public session to obtain the PhD Degree in

Transportation Systems

Jury final classification: Pass with Distinction & Honour

2025

UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR TÉCNICO

Mobility as a Service: A tool for steering mobility and fostering equitable transport worldwide

Mauricio José Orozco Fontalvo

Supervisor: Doctor Filipe Manuel Mercier Vilaça e Moura

Co-Supervisor: Doctor Óscar Oviedo-Trespalacios

Thesis approved in public session to obtain the PhD Degree in

Transportation Systems

Jury final classification: Pass with Distinction & Honour

Jury

Chairperson: Doctor Luís Guilherme de Picado Santos, Instituto Superior Técnico, Universidade de Lisboa

Members of the Committee:

Doctor Maria do Rosário Maurício Ribeiro Macário, Instituto Superior Técnico, Universidade de Lisboa

Doctor Filipe Manuel Mercier Vilaça e Moura, Instituto Superior Técnico, Universidade de Lisboa

Doctor Sara Maria Pinho Ferreira, Faculdade de Engenharia, Universidade do Porto

Doctor Paulo Jorge Gomes Ribeiro, Escola de Engenharia, Universidade do Minho

Doctor João Miguel Fonseca Bigotte, Faculdade de Ciências e Tecnologia, Universidade de Coimbra

Doctor Joaquim Miguel Gonçalves Macedo, Universidade de Aveiro

Funding institutions: Fundação para a Ciência e a Tecnologia (FCT) & CERIS

2025

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, I used ChatGPT as a grammar checker and to enhance readability in some sections. However, the study's insights, hypotheses, and interpretations were developed exclusively by the me.

Financial support

This research is funded by Fundação para a Ciência e Tecnologia FCT, Portugal, via grant [UI/BD/153578/2022] that was partially carried out at the Civil Engineering Research and Innovation for Sustainability CERIS funded by FCT in the framework of the project [UIDB/04625/2020] and I.P. under the Project with the reference PTDC/GES-TRA/3353/2020 (MASTI PROJECT)

Abstract

Technological innovation is making platform-based economies increasingly inevitable. In urban transport, Mobility as a Service (MaaS) systems aim to digitalize mobility by integrating multiple transport modes—along with ticketing, booking, and planning—into a single digital platform. However, MaaS faces several challenges that must be addressed to encourage adoption and fully realize its benefits.

This thesis offers a comprehensive perspective on how the MaaS ecosystem can evolve from its current limitations into a viable, equitable, and effective mobility solution. To achieve this, I conducted a comprehensive data collection effort that included a systematic literature review, a local survey in the Lisbon Metropolitan Area, a global survey spanning ten cities from both the Global North and South, and interviews with key MaaS stakeholders. These data were analyzed using a combination of quantitative methods (i.e., structural equation modeling, cluster analysis, and generalized linear models) and qualitative approaches (i.e., the Resources, Opportunities, Outcomes, and Well-being framework, Multi-Level Perspective, and meta-governance theories).

The findings reveal a significant gap in the literature regarding MaaS and equity: most studies overlook this dimension. In response, I propose a new conceptual approach that places equity at the core of MaaS evaluation and introduce a methodology to operationalize this in assessments. Additionally, the cross-sectional analysis suggests that MaaS has the most significant potential in cities with low modal integration and low commuter satisfaction. Bundle preferences vary by network conditions; hence, I designed tailored MaaS packages for different user profiles and mobility landscapes, including non-personal services such as food delivery. Finally, I identify critical barriers to MaaS adoption, such as digital literacy, and present a decision-support tool to help define the most appropriate role of public authorities in MaaS implementation.

Keywords

Mobility as a Service (MaaS), MaaS Governance, Transport equity, Cross-Sectional MaaS, Mobility Digitalization

Resumo

A inovação tecnológica está a tornar as economias baseadas em plataformas cada vez mais inevitáveis. No transporte urbano, os sistemas de Mobility as a Service (MaaS) visam digitalizar a mobilidade, integrando vários modos de transporte — juntamente com bilhética, reservas e planeamento — numa única plataforma digital. No entanto, o MaaS enfrenta vários desafios que devem ser abordados para incentivar a adoção e aproveitar plenamente os seus benefícios.

Esta tese oferece uma perspetiva abrangente sobre como o MaaS pode evoluir das suas limitações atuais para uma solução de mobilidade viável, equitativa e eficaz. Para tal, realizei um esforço holístico de recolha de dados que inclui uma revisão sistemática da literatura, um inquérito local na Área Metropolitana de Lisboa, um inquérito global em dez cidades do Norte e do Sul Global e entrevistas com as principais partes interessadas do MaaS. Esses dados foram analisados por meio de uma combinação de métodos quantitativos (como modelagem de equações estruturais, análise de cluster e modelos lineares generalizados) e abordagens qualitativas (como a estrutura de Recursos, Oportunidades, Resultados e Bem-estar, Perspetiva Multinível e teorias de meta-governança).

Os resultados revelam uma lacuna significativa na literatura sobre o MaaS e a equidade: a maioria dos estudos ignora esta dimensão. Em resposta, proponho uma nova abordagem conceitual que coloca a equidade no centro da avaliação do MaaS e introduzo uma metodologia para operacionalizá-la nas avaliações. A análise transversal sugere que o MaaS tem o maior potencial em cidades com baixa integração modal e baixa satisfação dos passageiros. As preferências de pacotes variam de acordo com as condições da rede e desenvolvi pacotes MaaS personalizados para diferentes perfis de utilizadores e cenários de mobilidade, incluindo serviços não pessoais, como a entrega de comida. Por fim, identifico barreiras críticas à adoção do MaaS — como a literacia digital — e apresento uma ferramenta de apoio à decisão para ajudar a definir o papel mais adequado das autoridades públicas na implementação do MaaS.

Palavras-Chave

Mobilidade como um serviço (MaaS), governação de MaaS, equidade nos transportes, MaaS transversal, digitalização da mobilidade.

Acknowledgements

My PhD journey has definitely been a rewarding experience, a rollercoaster of emotions and challenges, marked by essential milestones in both my professional and personal life. I want to express my sincere gratitude to all the amazing people who have supported me over the past four years. First of all, I would like to thank my wonderful wife, who chose to pause her career and leave a comfortable life in our country to support me in this adventure. I know these years have been tough, but none of this would have been possible without having you by my side, and I will be forever grateful for this.

I would also like to thank Prof. Filipe Moura for believing in me from the start and for giving me the freedom to determine the direction of my research, even when it sometimes seemed risky or too ambitious. I'm utterly convinced that I made the best choice by appointing you as my supervisor. I've learned a lot from you. Thank you for your availability every time I needed you, and for putting the person before work. To Professor Oscar Oviedo-Trespalacios, thank you for hosting me at TU Delft and for providing valuable academic and career advice. Your guidance helped me gain a different perspective on my research, making it more impactful.

Thanks to my family, to my mom, who always pushed me to keep moving forward and encouraged me always to dare to try, for all her support and advice, I LOVE YOU, MOM; to my father, brother, and sister for being there and being a massive part of my motivation to accomplish this objective. To Perla, who is sadly no longer with us, but who stayed with me for hours while I worked on this research and forced me to take active pauses.

I'm forever grateful to the professor's and researchers who believed in this project and trusted me by leading the data collection in their cities, this research would have not been as impactful without your contribution: Prof. Sonia Mangones and Lenin Bulla in Bogota; Prof. Sylvia He in Hong Kong; Prof. Mohammed Abouelela in Cairo; Prof. Hannah Hook in Ghent; Jorge Bolívar In Barranquilla; Dr. Margareth Gutierrez in Santiago; Prof. Sergio Useche in Valencia; Dr. Marc Hasselwander in Manila and Ana Karina Christ in Porto Alegre.

Last but not least, I would like to thank my colleagues, fellow researchers and friends for all the discussions, life sharing experiences, (bad) coffee's and beers: Gabriel Valença, Miguel Costa, Rosa Félix, Freddy Nogueira, Fesseha Belay, Juan Zuluaga and Maria Alfageme from IST, to the Doctoral Training Network for letting me be a member of its community, where I learned many, many things, traveled a lot and most importantly met wonderful people that I can call friends now, Shadi Haj-yahia, Maria Savall, Jaime Sierra, Gabriele Dell'Orto, Siyu Li, Xin Su, Seshadri Naik, Christelle Hadad, Ahmad Aiash and of course to its director Benjamin Buttner (no more bridges I promise!) and his team Corinna Niederreiter and Aaron Nichols. A huge thanks to Teresa Afonso for her help and patience with all the administrative tasks I needed to complete. To all my friends back in Colombia, I miss you all and hope to see you soon to celebrate the way it is deserved!

There is still one little person who I'm thankful for coming to my life, and I dedicate this work to my baby boy Luca. I hope Dad makes you proud!

TABLE OF CONTENTS

LIST OF ACRONYMS

- EU: European Union
- GDP: Gross Domestic Product
- GLM: Generalized Linear Model
- HDS: Home Delivery Services
- ICT: Information & Communication technologies
- IMPReSS: Information, Multimodal, Price, Reservation, Subscription & Societal Goals
- KPI: Key Performance Indicator
- MaaF: Mobility as a Feature
- MaaS: Mobility as a Service
- MLP: Multi-Level Perspective
- MGSEM: Multigroup Structural Equation Model
- PAYG: Pay-as-you-Go
- PT: Public transport
- PTA: Public Transport Authorities
- RH: Ride-hailing
- ROOW: Resources, Opportunities, Outcomes & Well-being
- RWA: Real-World-Applications

- SEM: Structural Equation Model
- STI: Socio-Territorial Inequalities
- SWOT: Strengths, Weaknesses, Opportunities, and Threats
- TOD: Transit Oriented Development
- UITP: Union Internationale des Transports Publics
- UTAUT: Unified Theory of Acceptance and Use of Technology
- UTAUT2: Unified Theory of Acceptance and Use of Technology (Extended)
- VKT: Vehicle Kilometres Travelled

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Several new shared mobility services, such as bike-sharing, car-sharing, and e-scooters, have been booming worldwide. If properly integrated with public transport (PT) and ride-hailing services, these can constitute an alternative to private car use by offering multimodal mobility access instead of ownership, i.e., Mobility-as-a-Service (MaaS). MaaS has been defined as "a *concept that integrates existing and new mobility services into <u>one single digital platform,</u> providing customized door-to-door transport and offering personalized trip planning and payment options*" (Durand et al., 2018). It was also referred to as a type of service that, through a joint digital channel, enables users to plan, book, and pay for multiple types of mobility services (Smith and Hensher, 2020a). It should consider at least the following: multiple modes of transport (public and private), a single application, a user-oriented approach, mobility packages, real-time information, a multimodal journey planner, and payment integration (Arias-Molinares and García-Palomares, 2020a). This provides a "one-fits-all" app that could revolutionize the future of urban transport.

1.1 Background and motivation

Current MaaS research has focused on business models (Chinaei et al., 2022; Ho et al., 2021, 2018), theoretical conceptualizations (Arias-Molinares et al., 2022; Esztergár-Kiss et al., 2020), travel behavior impacts (Durand et al., 2018; Kamargianni et al., 2016; Tsouros et al., 2021), implications of local policy and governance (Audouin and Finger, 2018a; Docherty et al., 2018; Meurs et al., 2020; Smith et al., 2018b; Vij and Dühr, 2022) and end-users perception (Jittrapirom et al., 2017; Kanuri et al., 2019). A few other MaaS review papers have also examined their impacts on environmental sustainability issues (Butler et al., 2020; Storme et al., 2021) and their effects on social conditions (Butler et al., 2021a).

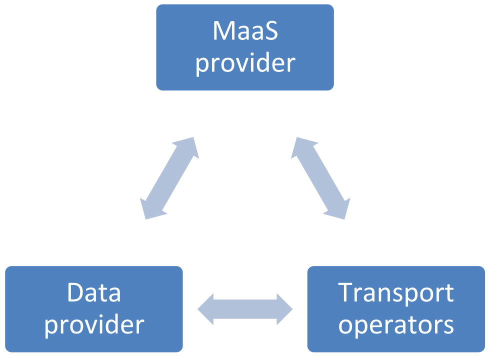
One of the defining characteristics of MaaS is its integration. According to Sochor et al. (2018b), a MaaS system can be categorized into four levels based on the features it should encompass (Figure 1). While this classification provides a simple framework for understanding MaaS, it has several limitations, which will be discussed in Chapter 4. Notably, the highest level of integration (societal goals) remains a significant gap in many MaaS initiatives.

Regarding MaaS benefits, the evidence is scarce as it has yet to be fully developed or implemented on a large scale. However, the literature suggests that it could enhance service quality, provide more accurate data and mobility information (for both users and brokers), and offer competitive pricing (Arias-Molinares and García-Palomares, 2020a). Additionally, the possibility of planning trips and being offered a wide range of transportation alternatives could encourage users to shift from private cars to active modes (Smith and Hensher, 2020b). MaaS has shown, in limited cases, to make it easier for citizens to access and utilize several complementary mobility services (Sochor et al., 2016). Other outcomes associated with MaaS systems include: (a) reduced Vehicle Kilometers Travelled (VKT) per capita; (b) increased trip awareness and planning; (c) reduced parking demand; (d) reduced private vehicle ownership; and (e) improved social equity (Butler et al., 2021b).

On the other hand, Pangbourne et al. (2020a) highlight that MaaS could compete with active modes, which is undesirable as it contradicts the goal of enhancing sustainability. Additionally, the current structure (Figure 2) risks sidelining governance, leading to "transport gentrification" and loss of institutional capacity (Pangbourne et al., 2020a).

Figure 1. MaaS integration levels (Sochor et al., 2018b)

Figure 2. Traditional MaaS scheme



Docherty et al. (2018) argue that the state must intervene in transport governance, as unregulated smart mobility solutions may exacerbate long-standing transport problems, particularly in urban areas. This concern adds to broader discussions on MaaS and social exclusion, given MaaS's novelty and its platform-based operations, users' adoption is yet to be defined. Moreover, a fully digital access system may create a barrier for the digitally unskilled population (Yan et al., 2021) or pose a risk of social exclusion if the price is too high. (Ho et al., 2018; Tsouros et al., 2021). Moreover, challenges such as limited internet access and recent evidence indicating that shared mobility services – key components of MaaS - are expensive and primarily used by high-income individuals (Orozco-Fontalvo et al., 2022) raise concerns about transport equity and user adoption. MaaS research has addressed the equity dimension from a rhetorical perspective, being mentioned in many studies, but without a concrete analysis of proposals to efficiently incorporate it into its operation and implementation.

I refer to equity as focusing on achieving fairness and considering individual circumstances, a different concept from equality that fosters uniformity and equal access to rights (Minow, 2021). Both concepts are crucial for social justice. In the case of MaaS (as further discussed in Chapter 2), it is worth assessing its impact on socio-territorial inequalities to identify whether it offers disparate conditions for distinct socioeconomic groups (Banister, 2018)... However, it is also important to assess whether MaaS can also improve transport conditions in different scenarios, for users with different needs and in different regions, thereby creating a fair transport system. Martens et al. (2019) define equity and justice as "the morally proper distribution of benefits and burdens over members of society", which MaaS should help to achieve in the transport ecosystem.

Identifying these barriers is essential for developing viable alternatives and solutions in advance. Within this framework, Table 1 summarizes the potential impacts of MaaS implementation through a Strengths-Weaknesses-Opportunities and Threats (SWOT) framework, providing an overview of both its benefits and risks.

Table 1. Possible impacts of MaaS implementation (SWOT)

SWOT CATEGORY	ITEM	DETAIL
STRENGTHS (S)	Digitalization	Better information for users about transport options
	Access-based transport	No need to own a car or bike
	Suburban areas	Better offer of transport services
WEAKNESSES (W)	Digitalization	Mistrust in digital apps (privacy issues and credit card)
		Internet access or skill
	Costs	Shared services are not always cheaper than private ones
		"Powerful" smartphones needed plus data plan
	Access-based transport	Shared cars will be available only to those who can afford it and have a license
	Suburban areas	Low profit

SWOT CATEGORY	ITEM	DETAIL
OPPORTUNITIES (O)	Costs	Possible lower fares by scale economies
	Governance	Improvement of urban plans (if included)
THREATS (T)	Digitalization	Technological “gentrification”
	Costs	Profit needed by the MaaS provider
	Governance	Loss of institutional capacity
		Transport “gentrification”

Notes: Strength is an internal capability or advantage, while an Opportunity is an external condition that the system can leverage. Also, a Weakness is an internal limitation or flaw, while a Threat is an external risk or challenge.

Source: author from *(Kloeke, 2020; Pangbourne et al., 2020a; Smith and Hensher, 2020a)*

In summary, the path to a MaaS will not be hindered by technological development, but rather by governance issues (Arias-Molinares et al., 2022). MaaS implementation will challenge governance and frame policy in new ways. According to Dowling (2018), the characteristics of a smart mobility system are not aligned with traditional, legally defined, or socially accepted categories of transport governance, which could lead to potential conflicts or difficulties. Although some MaaS studies address governance, most do not clearly define the public sector’s role in its development. Among those that do, few offer a concrete or replicable tool to support that definition comprehensively, an important gap this thesis seeks to fill.

Regarding user adoption, I argue that the one-fits-all premise does not apply to transport innovations (Pickford and Chung, 2019; Rogers, 2003). As such, MaaS must be designed with a context-specific perspective, considering not only institutional differences but also sociocultural patterns that influence individuals’ acceptance of the service, which may dictate the degree of their acceptance. Hence, understanding these differences is crucial for an effective design. To this end, I conducted a cross-sectional study on the acceptance of MaaS.

Meanwhile, some authors and operators are already ditching the MaaS concept, as the complexities of integration and financial feasibility seem difficult to overcome. However, exploring different governance models can shed light on the issue. Rather than abandoning the concept, I propose a new approach and explore the evolution of MaaS to go beyond personal mobility services. This aligns with the idea of Mobility as a Feature (MaaF) (Hensher and Hietanen, 2022), which proposes mobility services to be integrated into other sectors, such as housing, employment, and entertainment. By expanding its scope, MaaS could enhance its value proposition, improve financial feasibility, and create a flexible system that better serves users' needs.

1.2 Research questions & objective

These ideas, along with the key challenges and opportunities introduced throughout this introduction, will be explored in depth in the following chapters. I will provide a detailed analysis of these topics, supported by conceptual and empirical studies conducted to test and refine the arguments presented here, and address the question: *How can MaaS evolve from its current limitations to become a viable, equitable, and useful mobility solution?*

Based on the foregoing, three fundamental questions are raised:

1. *To what extent do the current conceptualizations, approaches, and topologies of MaaS support an equitable transport system?*
2. *What are the needs, preferences, and behaviors of users in relation to MaaS services and bundle configurations?*
3. *What regulatory roles and strategic actions should public authorities undertake to effectively govern and implement MaaS?*

Aiming to address these questions, the main goal of this thesis is to develop a comprehensive perspective on how the MaaS ecosystem can evolve from its current limitations to become a viable, equitable, and useful mobility solution by:

1. Identifying the socio-territorial implications of MaaS
2. Exploring new venues to make MaaS more attractive for different stakeholders.
3. Designing a comprehensive MaaS classification method.
4. Developing a global “MaaS acceptance model”.
5. Exploring MaaS bundle’s preferences across different contexts.
6. Evaluating the possibility of including non-traditional mobility services in MaaS offerings.
7. Identifying the minimum resources needed to be able to access MaaS.
8. Propose a context-specific flow-chart to define the public role in MaaS operation and integration.

The primary contributions of this research aim to fill the existing literature gaps by providing decision-making insights into the design, implementation, and operation of MaaS. This research will provide a baseline for MaaS system development worldwide. Additionally, it will be (to date and to the best of my knowledge) the first MaaS acceptance model to consider attitudes from 10 different cities, including those in the Global South, and address both physical and digital accessibility factors (Durand et al., 2022). Hence, this work will be of interest to transport authorities, operators, users, and academics in both national and international contexts.

1.4 Thesis outline

This dissertation is structured in three main parts, each comprising a set of chapters that collectively build a critical and comprehensive understanding of the design, implementation, and governance of Mobility as a Service (MaaS). The progression of the chapters reflects a deliberate analytical trajectory, moving from foundational concepts to user-centered empirical research, and ultimately to structural conditions and institutional roles.

Part I – Conceptual Foundations and Framing of MaaS

Part I establishes the conceptual and empirical foundation for the thesis. It begins with a review of existing MaaS implementations worldwide, identifying common structures, outcomes, and limitations. This is followed by a critical reflection on the prevailing conceptualizations of MaaS, proposing a new direction that prioritizes inclusiveness, adaptability, and equity, advocating for the need for public involvement in MaaS implementation. The final chapter in this section introduces a novel framework for classifying, comparing, and ranking MaaS systems, setting the stage for the user-centered analyses that follow. This part required no primary data and was built based on literature review and case studies.

Part II – User Acceptance, Preferences, and the Expansion of MaaS Services

Part II focuses on understanding MaaS from the user's perspective. It begins by examining who is most likely to accept and adopt MaaS on a global scale, drawing on survey results from ten cities across the Global North and South, and applying the Unified Theory of Acceptance and Use of Technology. The next chapter investigates how users prefer MaaS to be delivered, analyzing preferences for different bundle configurations based on commuter profiles and urban mobility contexts, applying cluster analysis and Borda count for ranking purposes. The final chapter in this section examines the characteristics of Lisbon respondents who expressed interest in incorporating non-personal mobility services (such as food delivery) into MaaS platforms, using a generalized linear model. Together, these chapters provide an understanding of user demand and expectations, while highlighting the need for flexible, context-sensitive system designs.

Part III – Structural Conditions and Governance of MaaS

Part III addresses the structural and institutional dimensions of MaaS implementation. The first chapter in this section presents an analysis of the resources and capabilities required for users to access MaaS. Intentionally placed after the preference-related chapters, it challenges the assumption that user intention alone can drive adoption. It argues that without access to enabling conditions such as digital literacy and affordability, MaaS remains an inaccessible option for many—regardless of interest or demand. To address this and mitigate the risk of exclusion, the final chapter shifts focus to the role of public authorities, introducing a decision-support tool to help them define their appropriate role in MaaS implementation based on local capacities and conditions. This section highlights the importance of governance and equity in determining the future viability and inclusiveness of MaaS systems.

The thesis concludes with a synthesis of the main findings, a reflection on their broader implications for research and policy, and a proposal for future work venues.

Outcomes & databases

Each of the chapters is a modified version of a published (or under review) journal or conference paper derived from this thesis; hence, it is indicated at the beginning of each chapter that they were "*partially published"* in a specific journal. A brief description of each is presented graphically in Figure 3, along with an indication of the type of scientific output it generated.

Three main databases were employed for the development of this thesis:

1. **MaaS global survey:** A survey designed by the author specifically for **part II** of the thesis, distributed in 10 cities, namely Barranquilla, Bogota, Porto Alegre, Santiago, Lisbon, Valencia, Ghent, Cairo, Hong Kong, and Manila. Researchers from these cities were involved in the data collection and translation stages of the study.

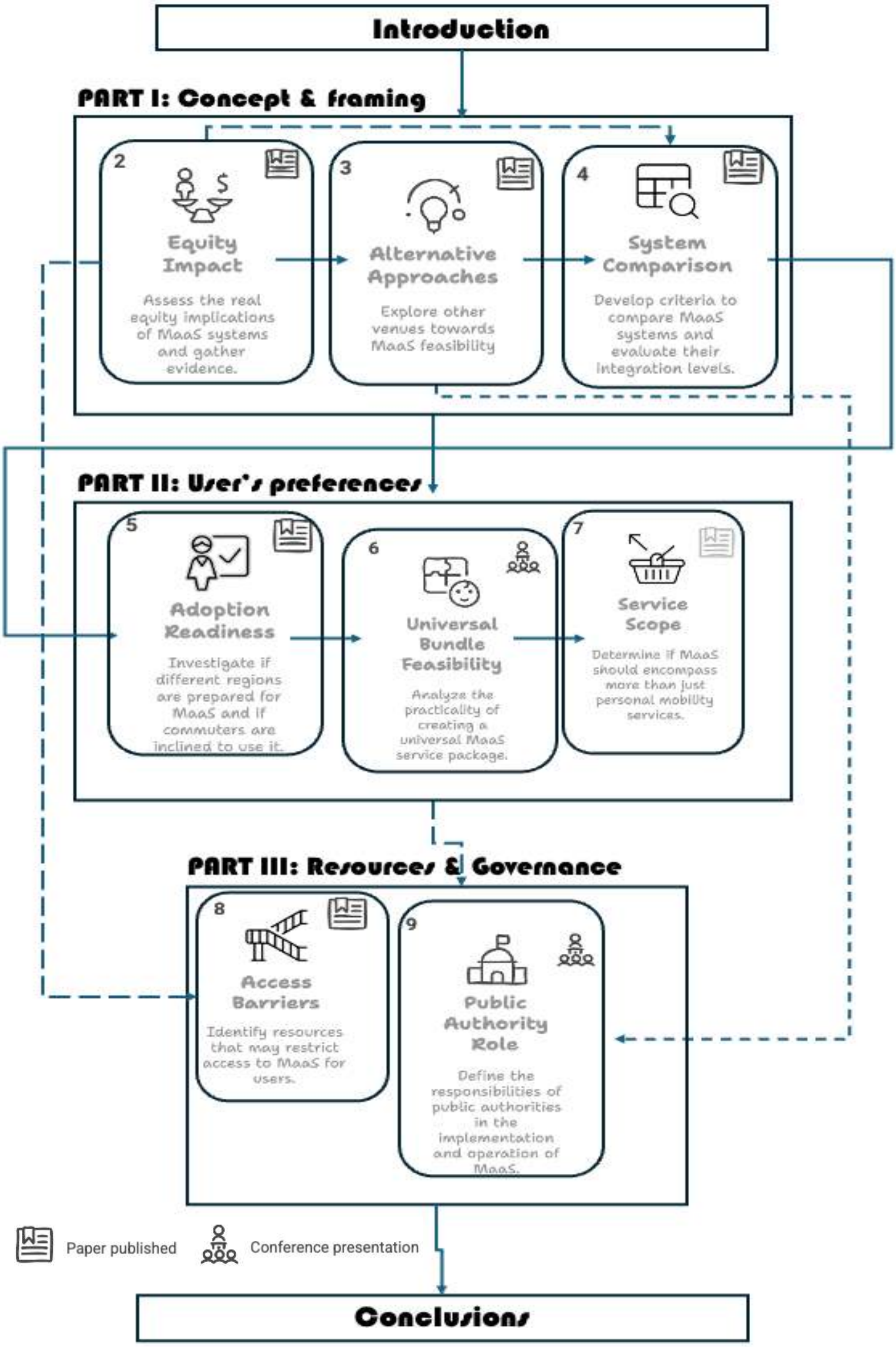
This survey had the following sections: Travel patterns, MaaS intention to use, Bundle design, Multimodal stress, and sociodemographics. A copy of the survey is included in the Appendix.

2. **MaaS and STI's survey:** A survey developed under the scope of the MASTI[1] to measure MaaS impact on socio-territorial inequalities and was employed for the development of Chapter 8. A copy of the survey is presented in the Appendix

3. **MaaS systems governance:** A dataset created by the author based on secondary sources to analyze governance models of 74 MaaS systems and initiatives. (available upon request to the author).

[1] https://www.mastiproject.online (PI: Prof. David Vale; Co-PI: Prof. Filipe Moura)

Figure 3. Thesis outline



1.5 Thesis outcomes

Journal papers

1. Mauricio Orozco-Fontalvo; André Soares Lopes; David Vale; Filipe Moura, “MaaS: Which resources are enablers, and who is being excluded?”, Transportation Research Part D: Transport and Environment (2025): https://doi.org/10.1016/j.trd.2025.104990 (Chapter 8) (Orozco-Fontalvo et al., 2025)

2. Mauricio Orozco-Fontalvo & Filipe Moura. “Should MaaS bundles include home delivery services?” Transportation Research Procedia (2025) https://doi.org/10.1016/j.trpro.2025.04.018 (Chapter 7) (Orozco-Fontalvo and Moura, 2025)

3. Mauricio Orozco-Fontalvo; André Soares Lopes; David Vale; Filipe Moura. "IMPReSS: A comprehensive method to classify MaaS systems". *Transport Policy* (2024): https://doi.org/10.1016/j.tranpol.2024.07.005 (Chapter 4) (Orozco-Fontalvo et al., 2024b)

4. Mauricio Orozco-Fontalvo; Filipe Moura. "Refocusing MaaS approach: A brief". *Transport Policy* (2023): https://doi.org/10.1016/j.tranpol.2023.08.002 (Chapter 3) (Orozco-Fontalvo and Moura, 2023)

5. André Soares Lopes; Maurício Orozco-Fontalvo; Filipe Moura; David Vale. "Mobility as a service and socio-territorial inequalities: A systematic literature review". *Journal of Transport and Land Use* (2023): https://doi.org/10.5198/jtlu.2023.2273 (Chapter 2) (Lopes et al., 2023)

Chapter 5 is currently under review in Transportation Research Part A: Policy & Practice; Chapter 9 is currently under review in Research in Transportation Business & Management.

Conferences

1. Mobility as a Service: Different cities, different needs? *International Transport Forum 2025, Leipzig, Germany*

2. Should MaaS bundles include Home delivery services? *EWGT 2024, Lund, Sweden*

3. Mobility as a Service resources: Who is being excluded? *HKTS Conference 2023, Hong Kong*

THIS PAGE WAS INTENTIONALLY LEFT BLANK

PART I

Conceptual Foundations and Framing of MaaS

To what extent do the current conceptualizations, approaches, and topologies of MaaS support an equitable transport system?

Sub questions:

1. *What is the actual equity impact of MaaS systems, and is there any evidence to support it?*
2. *Is there an alternative approach to make MaaS feasible?*
3. *How can we compare MaaS systems and identify their level of integration?*

Chapter 2. Mobility as a Service and Socio-Territorial Inequalities and inequities: A systematic literature review

This chapter was partially published as a journal article: Lopes, A.S., Orozco-Fontalvo, M., Moura, F., Vale, D., 2023. Mobility as a service and socio-territorial inequalities: A systematic literature review. JTLU 16, 215–240. *https://doi.org/10.5198/jtlu.2023.2273*

Summary

This chapter presents a systematic literature review of real-world MaaS applications and their effects on socio-territorial inequalities (STIs), applying the principle of distributive justice and adopting the Resources, Opportunities, Outcomes, and Wellbeing (ROOW) approach to assess the cases. From 2009 papers on MaaS, only 20 papers were identified as real-world applications that considered equity or equality impacts. Most studies were undertaken in Europe and Asia, neglecting places such as South America, Africa, and other low-income countries. They did not quantify the societal advantages of MaaS, while only a handful of studies investigated the influence of MaaS on STIs. Results indicate that MaaS schemes contain at least three factors that may drive inequality: the lack of basic resources to enter the system, the system's limited geographic coverage, or MaaS users may simply not gain from the system's intended accessibility benefits. In conclusion, MaaS could enhance trip planning and access to new modes and low-density areas; however, it is still perceived as expensive and only accessible to digitally literate individuals. This should be considered when defining MaaS governance, which remains (to date) underdeveloped, hindering private-public collaboration.

2.1 Introduction

In the XX century, mobility solutions were focused on private motor vehicles. Not only did these solutions alter the urban form (De Vos and Witlox, 2013; Lowry and Lowry, 2014), but they became a source of negative externalities, ranging from pollutant emissions (Banister, 2011), exposure to health risks ((Tranter, 2010), to social and territorial exclusion (Lucas, 2019; Mackett and Thoreau, 2015). To counteract these undesired effects, smart mobility was introduced at the beginning of the XXI century (Butler et al., 2021). Following the sharing economy trend (Ganapati and Reddick, 2018) and benefiting from advances in communication technologies, Mobility as a Service (MaaS) became a promising avenue for more sustainable, inclusive, and efficient mobility. However, despite interest from academia and other urban stakeholders, the practical benefits of MaaS concerning environmental and social challenges remain largely unknown (Arias-Molinares and García-Palomares, 2020b)

Current transport theory and practice give a central role to accessibility, both as one of the main aims of mobility planning (Deboosere et al., 2018; Handy et al., 2005) and as a non-material primary good to be taken into consideration from the point of view of justice (Pereira et al., 2017). The ability to easily reach a desired destination has tangible direct and indirect benefits for people's quality of life (Garcia et al., 2018; Lucas and Musso, 2014), and theories of justice indicate that a just system should aim for "the morally proper distribution of benefits and burdens over members of society"(Martens et al., 2019). Together with the land use system, access to transportation is crucial to guarantee social inclusion, as it offers equal access to opportunities such as employment, essential services, and recreational facilities (Butler et al., 2021a). However, access to opportunities is unfairly distributed within many territories and societies (Grengs, 2012; Pereira et al., 2017), indicating that transportation systems themselves are a source of unfairness (Gössling, 2016). In this context, I hypothesize that although MaaS was intended to be an efficient, sustainable, and convenient solution, its application in practice suggests that it could generate socio-territorial inequalities/inequities (STIs) if not adequately integrated. As such, in this chapter, I pose the question: ***What is the real equity impact of MaaS systems, and is there any evidence?***

MaaS is a recent concept, still evolving, which lacks a solid understanding (Arias-Molinares and García-Palomares, 2020b). Many authors have sought to address this gap by evaluating the state of the art. Several reviews have explored MaaS from different points of view. These include technological advancements (Palmer et al., 2018); business models (Durand et al., 2018), theoretical conceptualizations (Arias-Molinares and García-Palomares, 2020a); travel behavior impact (Kamargianni et al., 2016); the implications of local policy and governance (Santos and Nikolaev, 2021), and end-users' perceptions (Jittrapirom et al., 2017). Other reviews have examined the impacts of MaaS on environmental sustainability (Butler et al., 2020; Storme et al., 2021) and social conditions (Butler et al., 2020; Gompf et al., 2020)

It is interesting to note that all these authors recognize that MaaS may be a solution to current mobility problems, but while some recognize it as a potential source of inequality, none evaluate the relationship between MaaS and STIs or justice. I aimed to address this gap by examining accessibility for various social groups and geographic regions. The present chapter reviews the literature on real-world MaaS applications and evaluates their effects on STIs. The findings are structured into three main axes. First, defining the functional structure of MaaS, along with its promises and expected results. Second, identifying several components that can be used to evaluate transportation inequality: benefits and burdens, the affected members of society, and the underlying distributive principles. Third, investigating how the MaaS concept and current implementations perform in terms of equity and justice, with respect to access to the system itself, its impact on access to opportunities, its practical effects on societal behavior and perceptions, and its impacts on citizens' wellbeing (Martens et al., 2019). The results clarify the scientific and technical gaps regarding MaaS and geographical and social inequalities.

This review is structured into five sections, including this introduction (Section 2.1). Section 2.2 presents the concept, along with its expected benefits and burdens, and discusses inequality from a transportation perspective. Section 2.3 presents the methodology. Section 2.4 presents the main findings, and Section 2.5 discusses MaaS schemes and their association with STIs in depth.

2.2 Conceptual background

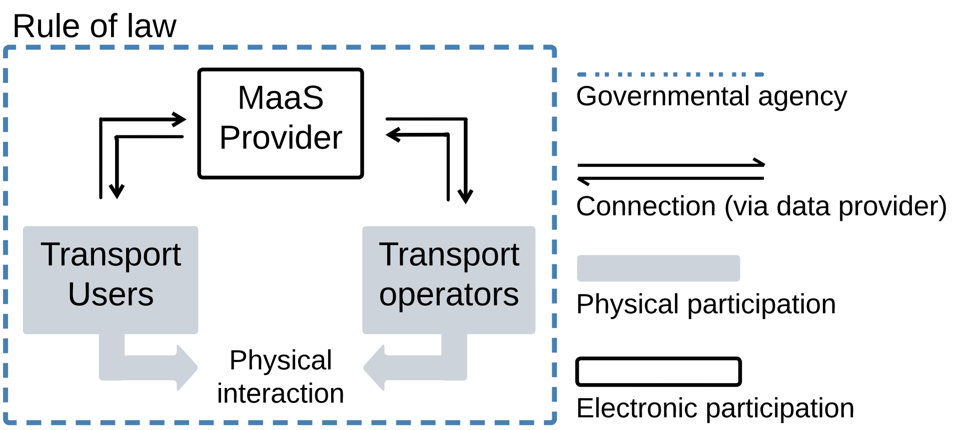
Although its practical benefits and future consequences are still largely unknown, mobility as a service (MaaS) has been growing worldwide since its first official appearance in 2014, in Finland. It promised a one-size-fits-all solution that could revolutionize the future of urban transport (Hietanen, 2014). According to Heikkila (2014), MaaS is "*a system in which a comprehensive range of mobility services are provided to customers by mobility operators*". In other words, it is a service that, through a shared digital channel, enables users to plan, book, and pay for multiple types of mobility (Smith and Hensher, 2020). An alternative definition is given by Durand et al. (2018), where it is envisaged as "*a concept that integrates existing and new mobility services into one single digital platform, providing customized door-to-door transport and offering personalized trip planning and payment options*". The latter definition emphasizes the requirement to meet the user's needs and integrate multiple modes within a single interface, typically involving the use of a portable device (such as a smartphone) connected to the internet. As the term suggests, the primary objective of MaaS is to enable individuals to access relevant opportunities without the need to own a means of transportation, thereby transforming mobility into a service that can be utilized whenever needed.

Several elements repeatedly appear in discussions about MaaS, including multimodality, the integration of transport modes, multi-party cooperation, user-centric services, tailor-made solutions, packaged or pay-as-you-go (PAYG) payment options, account registration, demand-oriented services, technology integration, and a single digital platform (Storme et al., 2021). Arias-Molinares and García-Palomares (2020) identified the following MaaS goals: to integrate smart mobility systems with public transport (PT) or traditional transportation modes while incorporating a user-oriented approach centered on a single mobile phone application that concentrates real-time information, a multimodal journey planner, and payment integration for multiple modes of transport (public and/or private) in the form of mobility packages.

2.2.1 MaaS: Structure and levels of integration

MaaS systems rely on the integration and co-operation of at least five key players: (i) transport users, i.e. customers who hire the mobility service to access a particular destination, (ii) transport operators (public and/or private) who supply the mobility service by providing their vehicle (with or without a driver), (iii) mobility brokers (also designated as MaaS providers), who sell the mobility service to users by providing a platform that connects and organizes interactions between them, (iv) data and technology providers, who operate telecommunications systems and supply technological solutions, and (v) policymakers, i.e. public authorities who are responsible for enforcing regulations and protecting societal goals (Wong et al., 2020; Zhang and Zhang, 2021). Conceptually, customers (users) interact with suppliers (operators) via a mediator (the mobility broker). This interaction relies on existing channels (data/tech providers), while all players are subject to governmental agencies (policymakers) (Figure 4).

Figure 4. Simplified MaaS scheme, showing the five key players.



In practice, the level of participation of these key players is not always balanced. The relationship between government and non-governmental players may vary, depending on the political environment, the level of regulation, and how public contracts are awarded (Wong et al., 2020). How MaaS schemes allow these players to interact illustrates how interconnected and integrated the solution is. If we take a multilayered scheme as a practical example, the first interaction layer emerges as transport users access information through a technological solution. A second layer comprises the mobility broker, who acts as an intermediary between transport users (customers) and the timetables and itineraries provided by operators. A third layer consists of physical interactions between transport users and vehicles supplied by operators. These layers are not necessarily chronologically or spatially ordered—illustrated by the overall interaction between users, operators, brokers, regulatory agencies, or other law enforcement bodies. How these parts and actors interact is a key element in discussions about MaaS integration.

2.2.1.1 MaaS integration

Several authors have defined a schema to characterize transportation systems in terms of the level of MaaS integration (Table 2). For example, Sochor et al. (2018a) and Ho et al. (2021) identify four incremental levels: the integration of information; booking and payments; bundled services; and societal values. The latter authors note that the main limitation in current MaaS systems relates to the highest level—the integration of societal goals. Alternatively, Lyons et al. (2019) interpret integration from the perspective of the cognitive effort of users. They identify five levels: no integration; the integration of operational and multimodal information; the integration of limited modes; the integration of all modes in certain circumstances; and the integration of all modes in all circumstances. Finally, Bandeira et al. (2022) state that current analyses of MaaS integration levels neglect important dimensions such as geographic coverage and sustainability. They propose six categories: environmental policy, social cohesion, personalization, IT integration, multimodality, and geographic area, rating each category from 0 to 5 to provide a final score based on the sum of the scores for each category.

Table 2. Current characterizations of MaaS integration levels.

Level	Sochor et al. (2018)	Ho et al. (2021)	Lyons et al. (2019)
5	N.A.	N.A.	Full integration: operational, informational, and transactional integration for all journeys
4	Societal goals integration: policies, incentives, etc.	Societal goals integration: policies, incentives, etc.	Full integration under certain conditions: not all modal combinations offer a fully integrated experience
3	Service integration: contracts, bundles, subscription, etc.	Service integration: contracts, bundles, subscriptions, etc.	Partial integration: some journeys offer a fully integrated experience
2	Booking/payment integration: trip-find, book, and pay	Booking integration: public or deep linking, or via an API Payment integration: single payment to all providers, payment for monthly trips	Limited integration: information integration across some modes with operation integration
1	Information integration: multimodal travel and price planner	Information integration: multimodal travel and price planner	Basic integration: information integration across (some) modes
0	No integration: separate, individual services	No integration: separate, individual services	No integration: no operational information or cross-mode transactions

The above approaches exemplify attempts to characterize MaaS integration, but they are not without limitations. For example, it is not immediately obvious what being a level 4 MaaS system means, beyond the number. Furthermore, characterizations are assumed to be incremental; for instance, a system that is classified as level 4 is assumed to encompass the benefits of all the lower levels. However, this may not be true, as a system may meet level 2 requirements, but not those of level 1. This point is illustrated by ride-hailing companies (also known as transportation network companies) that allow single-trip planning and payment, but do not offer multimodal integration. Although the approach presented by Bandeira et al. (2021) introduces more dimensions, it assigns the same weight to all categories, which can be misleading when assessing the system from a sustainability or equity perspective. Moreover, the final scores lack meaning and only allow a numerical comparison of levels. These observations highlight that the literature lacks a descriptive system that makes it possible to rank and compare different MaaS systems, using societal impact as a cornerstone. Such a methodology would allow practitioners and researchers to characterize, identify, and properly assess different MaaS systems.

2.2.1.2 Benefits and burdens

MaaS is expected to bring benefits to a wide range of stakeholders. Users are expected to have a better (more intuitive) experience, increased access to opportunities, lower transportation costs, shorter journey times, reduced car dependency, and better well-being. The public sector is expected to benefit from better transport information, better resource allocation, fewer traffic accidents, and a more reliable system. Operators are expected to benefit from access to a new, profitable market, enhanced traditional transport options, and the expansion of business opportunities for data providers.

However, there is little empirical evidence of the benefits of MaaS. Reported outcomes include a reduction in per capita vehicle kilometers traveled, increased trip awareness and planning, a potential shift from private cars to active modes (Smith and Hensher, 2020c), reduced private vehicle ownership and parking demand, improved social equity, and a reduction in the impact of home and work locations on transport costs (Y. Wong et al., 2020). MaaS is also reported to potentially improve service quality, supply better data and mobility information (for both users and brokers), and increase price competition (Arias-Molinares & García-Palomares, 2020). It has, in a few limited cases, been shown to make it easier for citizens to access and utilize complementary mobility services (Sochor et al., 2016).

On the other hand, the new MaaS paradigm could be a barrier in certain cases. In addition to the challenges faced by operators and the public sector, which encompass supply-side issues, along with governance and business models (Jittrapirom et al., 2017; Karlsson et al., 2020; Li and Voege, 2017a; Wong et al., 2020), these obstacles may also affect end users. Examples include economic barriers associated with bundled MaaS prices (Ho et al., 2018; Tsouros et al., 2021), technological barriers for less-proficient individuals (Yan et al., 2021), and geographic barriers stemming from the spatial and temporal coverage of systems (Butler et al., 2020).

The adverse effects of MaaS usage should also be taken into consideration. In particular, various attributes may prevent the system from reaching its full potential or even prevent users from accessing it. For instance, MaaS may compete with active transport modes or traditional PT systems (Smith et al., 2018b). This can happen when MaaS schemes do not incorporate incentives to meet societal goals (in terms of public policy), which is one of the most complex elements of MaaS integration. Such aspects are not discussed in the literature due to the lack of fully-fledged MaaS schemes.

2.2.2 Transport inequality and inequity

MaaS may have a negative impact on social and territorial equality. It is well-known that transport is a source of inequality, associated with social and territorial exclusion. Transport inequality is understood as differential access to transport conditions for distinct groups (Hidayati et al., 2021), while exclusion refers to a state where an individual or group is unable to participate in activities considered normal in a specific civil society (Pritchard et al., 2014). While there is a clear association between transportation inequality and poverty, it is also repeatedly linked to many other social issues (Gössling, 2016). A clear example of transport inequality relates to the conditions that users of private and public transport systems are subject to. Simply put, lower-income households have less access to both private vehicles and central locations, as prohibitive costs force them to reside in the most poorly served suburbs

(Fedorowicz et al., 2020). This creates a precarious situation for families that must rely on slower modes (compared to private vehicles) and endure longer commuting times in less comfortable conditions.

Other authors explore transportation inequality from different perspectives. Following Church et al. (2000), Lucas (2012) discusses the social exclusion aspect of transport, understood as difficulty in physically accessing opportunities that depend on transport systems. Transport exclusion reflects a disconnection between residents and many key activities. Banister (2018) sees transport inequality as the disparate conditions that exist for distinct socioeconomic groups when accessing transport infrastructure. Similarly, Lucas et al. (2016) discuss the concept of transport poverty, which encompasses the inability to afford transportation, a lack of transportation, and the difficulty of reaching key destinations. Gössling (2016) conceptualizes 'urban transport justice' as resulting from unequal risk exposure, the distribution of space, and the value placed on the transport time. Overall, these ideas bring the concept of transport inequality closer to that of (in)accessibility.

Pereira et al. (2017) develop the concept of distributive justice and argue that a deep understanding of justice in transport demand depends on a better understanding of accessibility and human capacity. Regarding equity, Martens et al. (2019) define it as "the morally proper distribution of benefits and burdens over members of society", and list three key components of transport equity: distributive principles that determine if a distribution is 'morally proper' or not; benefits and burdens; and the social groups affected by this distribution.

The first component – distributive principles – relates to several theories of justice that discuss the fair (or reasonable, or just) allocation of benefits and burdens in society. All plausible theories of distributive justice (utilitarianism, libertarianism, egalitarianism, justice as fairness, sufficientarianism, etc.),

The second key component of transport equity refers to the benefits and burdens that are used in its assessment. The choice of what to measure is important because decisions about how to supply or manage transport systems may create disparities among the social groups that compose society. In this context, Martens et al. (2019) organized benefits and burdens into the following four focal variables (tackling the social justice debate regarding the proper “focal variable” for these assessments), based on the social justice literature:

(1) **Resources (R)** relate to individual or household attributes (either owned or attributed by the environment). For example, owning a car, the availability of bicycle infrastructure, and access to an unpolluted environment.

(2) **Opportunities and risks (O)** relate to the implications of holding certain resources, as it is possible to have a resource but lack opportunities (e.g., a car owner who is banned from driving), while other conditions may pose a risk (cyclists who use unsafe infrastructure).

(3) **Outcomes (O)** are objectively measurable benefits or burdens (e.g., the number of trips, the time spent, expenses, and the number of car crashes).

(4) **Wellbeing (W)** refers to people’s subjective perception of their situation, which results from the interplay of resources, risks, and opportunities, outcomes, and context.

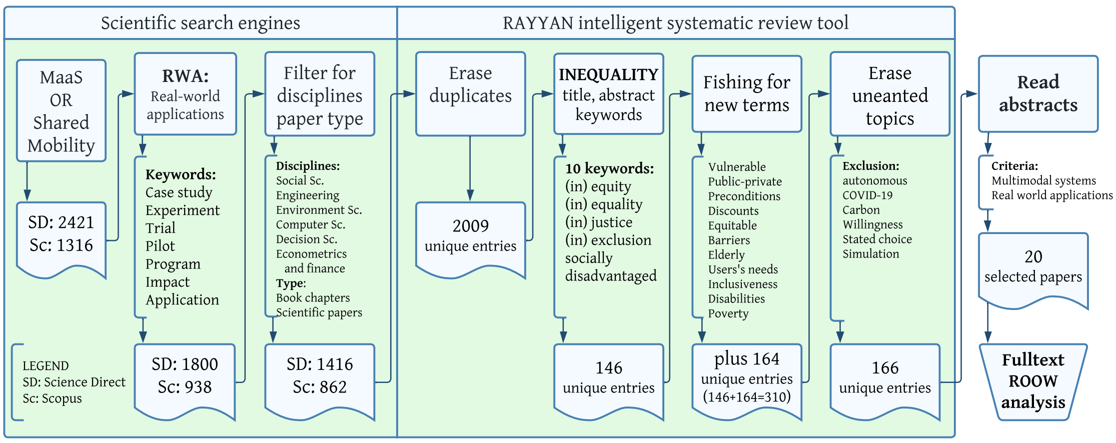
The third key component is the classification and identification of social groups that are affected by unfair conditions. This involves evaluating groups that are most likely to experience disadvantageous transport conditions. Several papers classify social groups based on, for example, income, gender, age, ethnicity, or disability (Hidayati et al., 2021; Soto et al., 2022; Wee et al., 2011). MaaS, like any other transport supply system, can affect equity conditions, especially in terms of accessibility. Linking MaaS integration levels with transport equity assessment tools, seen through the lens of accessibility, seems a plausible way to evaluate its impacts.

2.3 Systematic review methodology

This study presents the outcomes of a systematic literature review of MaaS studies, based on scientifically sound papers. A key incentive driving the deployment of MaaS systems is that they offer a competitive alternative to private cars, mainly due to solutions based on intermodality. Therefore, in this review, I understand MaaS as a system that integrates several modes (including shared mobility services), although, as stated in Section 2.1, integration levels are not incremental.

This study focused on real-world applications (RWA) of MaaS. Scopus and ScienceDirect metasearch engines were used to identify peer-reviewed articles or conference papers, while book chapters and the gray literature were not considered. The method is presented in Figure 5. The keywords used were 'MaaS' OR 'Mobility as a Service' OR 'Shared mobility' AND 'Case study'; 'Experiment', 'Pilot'; 'Trial'; 'Program'; 'Impact'; and 'Application' in the domains of Social Sciences, Engineering, Environmental Sciences, Computer Sciences, Decision Sciences, Econometrics, and Finance. Merging results from both search engines resulted in 2009 distinct papers. Next, the dataset was filtered to identify papers that assessed transport inequality. In this step, Rayyan software was used (Ouzzani et al., 2016) to enter 10 relevant keywords ((in)equity, (in)equality, (in)justice, (in)exclusion, socially, disadvantaged). This resulted in 146 distinct papers that had at least one of these keywords in the title, abstract, or as a keyword.

Figure 5. Flowchart showing the steps taken in the systematic literature review



Next, these preliminary results were used to expand the scope of the review. Specifically, 11 papers were 'fished' from within the pool of 146 preselected papers with inequality/equity-related keywords: vulnerable, public-private, preconditions, discounts, equitable, barriers, elderly, users' needs, inclusiveness, disabilities, and poverty, which helped us identify an additional 164 papers, bringing a total of 310. These were later filtered to exclude unrelated topics such as “autonomous vehicles” or “carbon emissions”. This resulted in a final total of 166 distinct papers. Then, abstracts of all these papers were read, and those that were not RWA-oriented (stated preferences, opinion-based surveys, etc.) were excluded, which limited the selection to 20 articles. These steps highlight that, despite the high number of recent articles on the topic of MaaS, assessments of the societal factor based on RWA or empirical data are scarce.

The findings reported in the selected papers were then evaluated in terms of how they reflected inequities associated with a MaaS scheme. The Resources, Opportunities, Outcomes, and Wellbeing (ROOW) approach was adopted (Section 1.1.1.2), as it provides an analytical framework for conducting a systematic equity analysis, extending beyond the equality concept to include fairness. Furthermore, it is one of the first approaches specifically designed to measure equity in the transportation sector. This approach focuses on the individual/user rather than other stakeholders, which could be a limitation. However, as I aim to identify STIs, it fulfills the requirements. Equity measurement in transport is still in the early stages of development; hence, there are no defined indicators to address it, as there are in other fields such as housing or health. Moreover, as a consequence of this, in transport studies, it is common to find a mix of these terms and a lack of clarity about which of them is being addressed; that is why, for this review, I analyzed both.

The analysis indicated that <u>Resources</u> (*R*) reflects access to MaaS schemes, in other words, how easily a potential user can use the system. <u>Opportunities</u> (*Op*) refers to accessibility provided by MaaS, in other words, how MaaS schemes enhance opportunities to reach desired destinations, based on people’s resources. <u>Outcomes</u> (*Ot*) refer to objective measurements of travel patterns (modal split, trip frequencies, costs, times, etc.) and activities (impacts on daily behavior). Finally, <u>Wellbeing</u> (*W*) refers to the travelers’ subjective assessment of their travel choices (comfort, safety, etc.).

The reported RWA case studies illustrated the four ROOW classes for each MaaS scheme. I searched for textual evidence associated with the core elements of each class (Table 3). Beginning with R, I searched for (direct or indirect) argumentative evidence of conditions that might affect access to the

MaaS system and classified them into six broad categories: *budget, location, readiness, savviness, vehicle, and infrastructure*. For instance, Resources were associated with a *budget* if the system had a minimum entry price. They were associated with *savviness* if they required an understanding of complex technology, and they were linked with *infrastructure* if access was hindered (by communication difficulties, difficulty boarding a vehicle, mode competition, etc.). The same logic was applied to the other three categories. Turning to *Op*, I classified opportunities into three categories based on *costs, time, or equity*. For instance, systems could have an observable effect on total transport expenditure (*costs*), the amount of time spent in transit (*time*), or differential access to opportunities (*equity*). Regarding *Ot*, benefits were identified if a paper reported changes in travel patterns resulting from MaaS usage. These changes were grouped into four categories (*distance/time, total trips, mode change, and preferences*) and reported either numerically (e.g., 20% increment in trip-chaining) or descriptively (e.g., a general reduction in kilometers traveled by car). Finally, for *W*, I searched for reports of travelers' opinions, perceptions, or any descriptions of satisfaction levels (e.g., the dropout percentage, opinions, and preferences).

Table 3. ROOW items identified

Resources	Opportunities	Outcomes	Wellbeing
Budget	Costs	Distance/Time	Positive
Savviness	Time	Total trips	Negative
Coverage	Equity	Modal change	
Readiness		Preferences	
Infrastructure			
Vehicle			

2.4 Case studies: Description and assessment of benefits/burdens

These findings indicate that only a few studies have investigated the impact of MaaS on STIs. While the majority of the MaaS literature cites potential concerns regarding increased STIs, this study focused exclusively on RWA studies. Table 4 lists the 20 papers identified for review and gives a short description of each case study's characteristics. The description encompasses sociodemographic and methodological aspects, as some studies examined the same sample population from different perspectives.

Table 4. Characterization of MaaS trials in chronological order of publication.

Reference	Case study	Sample	MaaS system	Assessment method
Sochor et al. (2016) Karlsson et al. (2016) Strömberg et al. (2018)	Gothenburg, Sweden 580k pop; $51,620 GDP/capita Modal share: PT 29%, auto 48%, bike 14%, walk 9%	195 people (173 adults): Mean age 38 91% daily app users 88% hold driving license 46% car owners Six-month field test	**UbiGo** (smartphone app) Include PT, taxi, car and bike sharing, rental cars Bundles from €135 or $185 per month	Questionnaires (pre, during and post-trial) + interviews + travel diaries
Smith et al. (2018b)	Sweden/Finland, no specific city	31 interviews with 34 key stakeholders from public, private and research sectors	Multiple systems: **IRIMS** framework	Semi-structured interviews

Reference	Case study	Sample	MaaS system	Assessment method
Chang et al. (2019)	**Taipei**, Taiwan 2.8mi pop; 9,918/Km^2; $33,000 Modal share: PT 39%, auto 39%, active 10% taxi 12%	1000 registered users 40km Taipei-Yilan corridor	**UMAJI** (full multimodal MaaS environment) Bundles $43/month Value services: gift, restaurants, accommodation.	Usage records during an open trial (2017 and 2018)
	Kaosiung, Taiwan 2.7mi pop; 7100/Km^2; $26,600 Modal share: PT 39%, auto 39%, active 10%, taxi 12%	15,492 packages sold 3-month operation targeted at students aged 17–22 and white-collar commuters	**MenGo** (smartphone app.) Including city and intercity buses, MRT, light rail, ferries, shared bikes. 4-month service packages	Usage records during an open trial (2018)
Kanuri et al. (2019)	Bangalore, India 10mi pop; 11000/Km^2; $3300 Modal share: PT 29%, auto 10%, bike 5%, walk 29%	93 regular users of integrated modes. 2 feeder and 1 parking services were piloted. At selected metro stations	**STAMP** (Station Access and Mobility program): Metro, parking, and feeder lines. App information systems available	Trial followed by a user survey.

Reference	Case study	Sample	MaaS system	Assessment method
Barbour et al. (2020)	**Florida**, USA (3 cities) 940k pop; $44.300 GDP/capita Modal share: PT 1,4%, auto 80% bike 0,7%, walk 1.43%	675 respondents	The **CycleHop** (incomplete MaaS system)	Questionnaire on travel behavior (ride sourcing users)
Böcker et al. (2020)	**Oslo**, Norway 640k pop; $87.000 GDP/capita Modal share: PT 39%, auto 36%, bike 7%, walk 18%	4.4 million trips in the bike sharing system	**CityBike** (PT and bike integration)	Assessed the effects of PT connectivity on total bike sharing frequency
Karlsson et al. (2020)	Gothenburg, Sweden 580k pop; $51,620 GDP/capita Modal share: PT 29%, auto 48%, bike 14%, walk 9%	83 households participated in a six-month trial	**UbiGo** (smartphone app.) Includes PT, taxi, car and bike sharing, rental cars in bundles, costing €135 to185 per month	Questionnaires + individual interviews
	Västra Götaland, Sweden	19 participants, potential investment's firms	**UbiGo** (smartphone app.) Includes PT, taxi, car and bike sharing, rental	Individual meetings + semi-structured interviews with

Reference	Case study	Sample	MaaS system	Assessment method
	1.7 mi pop; $47.280 GDP/capita Modal share: PT 21%, auto 52%, bike14%, walk 12%		cars in bundles costing €135 to185 per month	potential bidders
	Malmö/Lund, Sweden 350k pop; $55.340 GDP/capita Modal share: PT 15%, auto 58%, bike 16%, walk 11%	8 participants. Residents 100% car owners	**EC2B** (housing based MaaS service) Includes PT, shared bikes and cars, car rental, and delivery	Individual interviews
	Finland (whole) 5.5mi pop; $49.041 GDP/capita Modal share: PT 30%, auto 39%, bike 8%, walk 21%	9 stakeholders 3 mixed groups of firms and government	**Multiple platforms** (Whim, Tuup, Sonnera Reisu and Kätävä, and more)	Interviews with stakeholders + MaaS-related policy documents
Eckhard et al. (2020)	Finland 2 trials in 3 rural areas: 1.**Porvoo** 50k pop.	1) 69 users (363 trips; 281 routes; 15 respondents	**Kyläkyyti** (demand-responsive) Includes shared taxi, and minibus; APP and	End-user surveys and data provided by service providers +

Reference	Case study	Sample	MaaS system	Assessment method
	2.**Kuru** 3k pop. 3.**Vamala** 16k pop Finnish GDP/capita: $49.041	2) 9,442 trips; 5,727 trips	CALL center; €3 to €5 per trip	workshops, surveys, interviews, data collection.
Hesselgren et al. (2020) Zhao et al. (2020)	Stockholm, Sweden 1.6mi pop; 3,858/Km^2; 72,803 Modal share: PT 32%, auto 46%, bike 7%, walk 15%	15,000 participants 70 buildings Limited to the company area	Corporate MaaS Pilot: Includes taxis, shuttle and commuter buses, 40 shared e-bikes (no active modes)	Individual semi-structured interviews with users Travel logbook
Singh (2020)	**Kochi**, India 2.1mi pop; 7100/$Km^{2;}$ $3100 Modal share: PT 42%, auto 36%, bike 3%, walk 12%, alt. 7%	Open pilot (Dec 17–May 18) 9 key stakeholders invited (metro + 6 bus operators; rickshaw drivers; taxi drivers)	**Kochi One** (app + smartcard) Includes metro, buses, rickshaw, boats, and bikes	Stakeholder roundtable
Storme et al. (2020)	**Ghent**, Belgium 260k pop; $47.611 GDP/capita	100 participants from Ghent University. All were car owners, and smartphone + data plan owners	MaaS pilot (own app) Includes bike sharing and rental, car-sharing and rental, taxi, PT	Usage records during trial

Reference	Case study	Sample	MaaS system	Assessment method
	Modal share: PT 20%, auto 27%, bike 30%, walk 18%.	2.5 months in 2017		
Abdelwahab et al. (2021)	**Toronto**, Canada 2.7mi pop; $43.100 GDP/capita	16 planning districts 625 Traffic analysis zones Focus on under-resourced areas	No official name	Measured generalized cost of travel and accessibility levels Access profile analysis
Bauchinger et al. (2021)	**Graz**, Austria 500k pop; 1228/Km^2; $40000 Modal share: PT 20%, auto 42%, bike 19%, walk 19%	87 active users (registered)	**REGIOtim** e-carsharing + Charging Cycling + (Micro-Public transport	Analysis of potential locations for tim nodes. Pilot users survey;
Hensher et al. (2021a)	**Sydney**, Australia 5.4mi pop; $84,700 GDP/capita Modal share: PT 25%, auto 59%, bike 3%, walk 4%	92 participants: 100% iPhone users 100% IAG workers 2-year trial	**Tripi** (MaaS platform) Includes PT, rideshare, car share and car rental. PAYG/bundles from $25 to $125 per month	Observe the dynamic of monthly-bundle adoption and PAYG in distinct scenarios

Reference	Case study	Sample	MaaS system	Assessment method
Ho et al. (2021)	**Sydney**, Australia 5.4mi pop; $84,700 GDP/capita Modal share: PT 25%, auto 59% bike 3%, walk 4%	Five-month trial IAG Employees 150 potential participants 93 final participants	**Tripi (**MaaS platform) Includes PT, rideshare, car share and car rental. PAYG/bundles from $25 to $125 per month	Revealed preferences, pre- and post-trial surveys and interviews, Mixed logit modeling
Hult et al. (2021)	Pilots in rural areas in Sweden: 1. **Skattungbyn** (pop 293) 2. **Södra** Årefjällen 3. **Torhamn** (pop 421) 4. **Broddetorp**, Timmersdala Lundsbrun (pop 2500) 5. **Broddetorp** (pop 822)	1. Since Nov. 2018 2. Since Feb. 2020 3. Mar. 2018 to Apr. 2018 4. Since Oct. 2020 5. Aug. 2013 to Sep. 2018 27 interviews	1. **DalMaaS**: ridesharing + special transport 2. **FjällMaaS**: PT, bus service, delivery, and ridesharing 3. **Hämta**: Ridesharing + PT 4. **KomILand**: Car and bike sharing, and taxi 5. Mobil-samåkning: Ridesharing	Participatory observation and interviews with actors in five pilots
Jiao & Wang (2021)	New York City, USA	Trip data from Uber, Lyft, Citibike and taxis	No official name	Trip diary records from trial users

Reference	Case study	Sample	MaaS system	Assessment method
	19mi pop; $75.131 GDP/capita Modal share: PT 33%, auto 55%, bike 1%, walk 6%		Includes bikeshare, ride hailing, and taxis	

An initial examination of each trial's characteristics revealed some noteworthy first impressions. Only three studies were conducted in low-income nations (two of which were in India), raising concerns about MaaS affordability, equity, and the potential for transport gentrification. In terms of geography, most studies were undertaken in Europe and Asia, neglecting places such as South America and Africa. It should be noted that some studies do not present the case as a MaaS system; however, they were included because they addressed multimodality and transport integration.

Regarding the impact of MaaS on active travel and sustainable modes, while there was no direct mention of e-scooters, 16 of the 20 studies addressed bike-sharing (mainly e-bikes) in association with PT (although not the entire network in some cases). In general, the assessed studies explored a variety of modes and payment options, and, remarkably, some took place in rural or low-density areas, with the aim of evaluating the potential of MaaS to overcome transportation challenges in these locations.

The analysis revealed significant differences between trials concerning the context and the development stage. Due to the complexity of deploying a multimodal digital transport pilot, most cases were based on small samples, which jeopardized generalizing their results, as acknowledged by several authors (Kanuri et al., 2019; Barbour et al., 2020; Ho et al., 2021; Bauchinger et al., 2020; Storme et al., 2020; Hensher et al., 2021; Hult et al., 2021) highlighting the importance of conducting bigger pilots, some (Chang et al., 2019; Hesselgren et al., 2020; Jiao & Wang, 2021) used significantly bigger samples and treated participants as active system users. Finally, a few trials (Karlsson et al., 2020; Singh, 2020;

Smith et al., 2018) focused on the operator's point of view rather than users (and hence used a smaller sample).

2.4.1 Assessment of MaaS benefits/burdens based on the ROOW approach

In this section, the impacts identified in MaaS trials were evaluated with respect to the four classes of benefits/burdens (*ROOW*). Reported results were classified as a function of resource relevance for adoption, opportunities, outcomes, and whether there was a positive or negative effect on well-being. It should be noted that some papers reported no results regarding one or more of these items. Table 5 presents the results of the evaluation and lists the main conclusions for each of the four classes. It is interesting to note that, although some papers assessed the same trial, the results of the ROOW analysis offer different perspectives.

Table 5. Synthesis of the ROOW analysis for the selected papers.

Paper	Resources	Opportunities	Outcomes	Wellbeing
Karlsson et al. (2016)	(Coverage) Distance to car-sharing (Budget) Some did not join due to cost/benefit ratio	-	(Modal change) Decrease in private car use; Increase in alternative mode use; Overestimated importance of car	(Positive) Participants wanted to continue as customers (97%); Less positive towards private cars
Sochor et al. (2016)	(Budget) Price was a significant variable for system adoption (Coverage) Distance to car sharing sites	-	(Total trips) Overall reduction in private car trips (Modal change) Increased use of carsharing and express	(Positive) 75% were satisfied with the changes; Users less positive toward private cars 23%; More positive toward carsharing 61%, PT

Paper	Resources	Opportunities	Outcomes	Wellbeing
	(Savviness) Familiarity with the MaaS app and systems was a barrier		bus; Increased trip chaining; 20% changed routes and destinations	52% bikesharing 42%; Easy to pay and keep track of trip costs
Smith et al. (2018)	(Budget) Unsubsidized system (Coverage) Limited ticket booths (Savviness) Lack of data transparency	-	(Modal change) MaaS system adoption competed with PT	-
Strömberg et al. (2018)	(Coverage) Proximity to stations (Infrastructure) Service competitiveness needs high demand (economies of scale) (Vehicle) Access to cars	-	(Distance) Increased short trips; Longer planning times (Modal change) Access to more modes (diverse modal split); Adoption of healthier behavior (Preferences) Being a frequent PT user affected by bundle choices	(Positive) 93% satisfied with the system; 69% more satisfied with travel after trial; 79% wanted to continue to use the system
Chang et	(Budget) Limited by cost (bundle price)	-	(Modal change) Negligible shifts; 58,800	(Positive) 94% of users continued after

Paper	Resources	Opportunities	Outcomes	Wellbeing
al. (2019)			trips per month shifted from cars to greener modes (Total trips) More trips by users	the end of the 3-month trial
Kanuri et al. (2019)	(Budget) Tariff options ($/Km) (Infrastructure) Limited to metro feeder micro mobility	(Equity) Children and the elderly gained mobility (Time) Limited commuting time options (to work, from home)	(Modal change) Induced a 43% shift from private vehicles and 48% from PT for first and last miles segments.	(Positive) Good impact on time-savings perceptions (Negative) Low spatial coverage negatively affected perception of users
Barbour et al. (2020)	(Budget) User Income (Vehicle) Car ownership (Savviness) Willingness to use new transport modes (Coverage) Living within 1 mile of a grocery store	(Time) Time gains due to no parking	-	-
Böcker et al. (2020)	(Coverage) Proximity to dense areas; limited coverage	(Equity) Poor service for the elderly and women;	-	-

Paper	Resources	Opportunities	Outcomes	Wellbeing
	(Infrastructure) Uphill bike lanes (Readiness) Temporal limitations	few gains outside central areas		
Hesselgren et al. (2020)	(Savviness) App learning curve (Readiness) Time limited services (Infrastructure) Time and capacity limited services	(Time) Time gains due to no parking	(Modal change) Perceived change from walking to shuttle bus; ⅔ of employees who used to commute by car continued to do so; Increase in ride matching	(Positive) Mostly appreciated by employees (Negative) Problems with connections and battery life caused frustration
Karlsson et al. (2020)	(Coverage) Parking availability (Savviness) Steep learning curve (Budget) Service costs compared to current costs; Regular charging	(Costs) Minimized travel costs	(Preferences) Observed dropouts due to old habits	-
Storme et. al. (2020)	(Vehicle) MaaS could be seen as a complimentary service for private car users	(Equity) Children and the elderly became more mobile	(Modal change) Cars less used for commuting; Taxis and car-rental were unattractive; Own car is	(Positive) Bike was considered pleasant, convenient, and

Paper	Resources	Opportunities	Outcomes	Wellbeing
	(Savviness) App design and integration (e. g. trip planner) were a barrier		attractive if no sharing system is close by (Total trips) Higher trip frequency	environmentally friendly for short trips (Negative) MaaS can be stressful if not well organized
Eckhardt et al. (2020)	(Vehicle) Difficult to board vehicles; competition with private cars (Budget) Affordability (Infrastructure) Dependent on smartcard interoperability (Savviness) Digital illiteracy; lack of service awareness	(Costs) Reduced travel costs (Equity) Accessibility gains for rural areas	(Total trips) Less immobility (26%); Increased number of trips (Modal change) Increased modal shift, Reduced emissions (Distance) Reduction of 12.6% in km driven	(Positive) 73% preferred DRT over schedules + routes; Users extremely satisfied with service availability and transport arrival (from APP) (Negative) Dissatisfied with waiting time (by phone)
Singh (2020)	(Budget) Minimum tariff options (Savviness) Learning curve is a barrier (Coverage) Spatial constraints	(Costs) Minimized travel costs	(Modal change) High rickshaw usage rates	(Positive) Users felt the system was reliable

Paper	Resources	Opportunities	Outcomes	Wellbeing
Zhao et al. (2020)	(Savviness) Lack of info update; lack of service awareness (Budget) Limited incentives (Readiness) Time inflexibility; reliability of real time information	(Time) Reduced parking time (Equity) Little access to opportunities outside the company	(Modal change) 21% of respondents claimed they may shift from private car use to CMaaS	(Positive) Satisfaction rate 75% (Negative) Users felt the lack of a trip planning function was a drawback
Abdelwahab et. al. (2021)	(Budget) Ride haling cost per hour (Vehicle) Competition between ride haling and transit	(Costs) Minimized travel costs/time, fewer fares (Time) Distances to nearest stations	-	-
Bauchinger et al. (2021)	(Coverage) Distance to terminals (Budget) Affordability (Savviness) Age (Infrastructure) Internet coverage	-	(Modal change) 65% of members replaced cars (Preference) Pre-registration was a barrier for first-time users	-
Hensher, et al (2021)	(Savviness) Little knowledge about MaaS or trip planning technology	-	(Distance) Drop in car km/month	(Positive) All participants are very

Paper	Resources	Opportunities	Outcomes	Wellbeing
	(Budget) Limited transport budget; people chose bundles by price (Coverage) All participants were located close to PT		(Total trips) Affected usage levels (Preferences) Male participants and households with more driving licenses preferred PAYG over bundle	open to the idea of MaaS schemes
Ho et al. (2021)	(Infrastructure) non-customized solutions (Budget) Costs (Vehicle) Bundle adoption not affected by owning a car	(Equity) Children and elderly became more mobile	(Modal change) Monthly savings do not have to be overly large to influence MaaS adoption (Preferences) Willingness to be more sustainable is an incentive	(Positive) Cost feedback seen as a very positive feature by users
Hult et al (2021)	(Infrastructure) High dependency on tech providers, difficult to deploy innovation in rural areas (Savviness) Uncustomed solutions	(Equity) Risk of increased spatial injustice if PTAs only support communities with strong civic organizations.	(Preferences) Unsuccessful in attracting users for a long period; Solutions should be place-based and not one-size-fits-all	(Negative) Residents and tourists demand innovative, smart, climate-friendly options.

Paper	Resources	Opportunities	Outcomes	Wellbeing
				(Negative) Users require direct participation
Jiao & Wang (2021)	(Budget) High cost of on-demand ride services (ODRS) (Savviness) Lack of info about ODRS (Coverage) Limited geographical coverage	(Equity) ODRS improved mobility for challenged populations (Cost) Minimized generalized travel costs	(Distance) On-demand service rides are shorter than trips made by car or transit	-

A summary for each focal variable is presented as follows:

2.4.1.1 Resources

The reviewed articles suggest that access to MaaS systems is affected by six major factors (Table 2). They are:

I. <u>Budget</u> (cited in 15/20 papers): The impact of the service on the end user's budget, which determines whether an individual or family will be able to afford the provided service (e.g., price-based bundles, minimum entry costs).

II. <u>Savviness</u> (cited in 13/20 papers): How easy or difficult it is for potential users to understand, interact with, and benefit from the technological solutions that support service usage (e.g., a lack of updated info, app learning curve, awareness of existing systems).

III. Coverage (cited in 10/20 papers): Spatial availability, related to the distance between the origin/destination and the system's entry point (e.g., systems with limited geographical coverage, and other proximity challenges).

IV. Infrastructure (cited in 8/20 papers): The physical characteristics of the system provided to users (e.g., mobile data availability, tech interoperability, limited capacity).

V. Vehicle (cited in 6/20 papers): Limitations imposed by vehicle-based conditions, either from the user's or the operator's point of view (e.g., car ownership, difficulty in boarding vehicles, competition between transport modes).

VI. Readiness (cited in 3/20 papers): System and users' temporal availability or synchronicity (e.g., time-limited services, schedule reliability).

Only a few papers discuss inequality or equity in terms of resources. Both Jiao and Wang (2021) and Abdelwahab et al. (2021) extensively discuss locational inequality, while the latter also explores the unequal spatial distribution of benefits with respect to general costs for those who adopt integrated modes. Other papers only briefly mention possible equity benefits and do not debate the topic in detail.

2.4.1.2 Opportunities

Some of the reviewed papers recognize that MaaS-oriented systems might objectively affect users' access to opportunities. Although evidence was found on accessibility measurements in 13 of the 20 reviewed papers, the issue was not explored in detail; instead, the discussion was limited to three types of generic comments, presented below:

I. *Time* gains, in terms of commuting time, parking time, and shorter distances (Abdelwahab et al., 2021; Barbour et al., 2020; Hesselgren et al., 2020; Kanuri et al., 2019; Zhao et al., 2020).

II. *Cost*, in most cases (Abdelwahab et al., 2021; Eckhardt et al., 2020; Karlsson et al., 2020; Singh, 2020), costs were discussed in generic terms. Only one paper presented a detailed cost comparison (Jiao & Wang, 2021).

III. *Inclusion,* understood as better accessibility for mobility-challenged groups (such as older adults and children) due to MaaS usage, was mentioned in several papers (Böcker et al., 2020; Eckhardt et al., 2020; Ho et al., 2021; Jiao & Wang, 2021; Kanuri et al., 2019; Storme et al., 2020; Zhao et al., 2020).

Furthermore, it is noted that most papers that directly addressed societal impacts were focused on multimodal systems, and not specifically MaaS (within the scope of the concept defined in this review). While this could be due to the novelty of MaaS systems, researchers and practitioners should consider this point in the design and operation of services.

2.4.1.3 Outcomes

Reported outcomes could be classified into the following four categories:

I. Modal change (cited in 13/20 papers) relates to decisions taken by MaaS-system users to replace one mode with another. The analysis indicates increased usage of several modes (a more diverse modal split) (Eckhardt et al., 2020; Karlsson et al., 2020; Sochor et al., 2016; Strömberg et al., 2018), competition between MaaS systems and PT (Kanuri et al., 2019; Smith et al., 2018), shifts from cars to other modes (Bauchinger et al., 2021; Chang et al., 2019; Kanuri et al., 2019; Zhang & Zhang, 2021; Zhao et al., 2020), and cases where car users resisted change (Hesselgren et al., 2020)

II. Total trips (cited in 5/20 papers) refers to a change in the number of trips undertaken by participants. Such changes were either observed as a simple increment in the total number of trips (Chang et al., 2019; Eckhardt et al., 2020; Hensher et al., 2021; Storme et al., 2020) or as improved mobility. Other papers observed changes (notably, a decrease) in the total number of trips made by private car (Sochor et al., 2016).

III. Distance (cited in 4/20 papers) refers to the observed change in trip distance due to MaaS adoption. Results indicate that on-demand service rides are shorter than trips made by car or transit (Jiao & Wang, 2021), that there is a reduction in km driven per month (Eckhardt et al., 2020; Hensher et al., 2021), and that more short trips are made (Strömberg et al., 2018).

IV. Preference refers to behavioral change. This outcome encompasses the direct effects of MaaS adoption on participants' behaviors, excluding modal, distance, or frequency changes. It indicates difficulties in retaining MaaS users after the trial period (Hult et al., 2021) or its effects on users' values and habits (Ho et al., 2021; Karlsson et al., 2020).

Only a few papers reported no outcomes. Moreover, it is noteworthy that papers that were focused on operators (rather than users) reported limited observable outcomes and mostly relied on historical data.

2.4.1.4 Wellbeing

Well-being required an analysis that went beyond observations of system usage. Only studies that incorporated questionnaires and interviews reported well-being data. Seven papers did not report how participants subjectively perceived the implementation of MaaS-oriented systems. The other thirteen interpreted perceptions as positive or negative.

I. Positive feedback: In general this was reported in terms of: General satisfaction (Chang et al., 2019; Eckhardt et al., 2020; Hensher et al., 2021; Hesselgren et al., 2020; Singh, 2020; Sochor et al., 2016; Strömberg et al., 2018; Zhao et al., 2020), savings promoted by the system (Ho et al., 2021), a less positive attitude towards cars (Karlsson et al., 2016; Sochor et al., 2016), or a more positive attitude to alternative modes (Eckhardt et al., 2020; Sochor et al., 2016)

II. Negative feedback: Users were unhappy with limited coverage (Kanuri et al., 2019), technical shortcomings such as a lack of planning apps, or e-bikes with flat batteries (Hesselgren et al., 2020; Hult et al., 2021; Zhao et al., 2020), and waiting times (Eckhardt et al., 2020).

At least three papers are particularly notable. Strömberg et al. (2018) specifically focused on capturing users' perceptions and classified them into behavioral subgroups; Sochor et al. (2018) carried out an in-depth evaluation of satisfied users' motivations; and Eckhardt et al. (2020) used a satisfaction assessment to compare cases. However, none of the reviewed papers carried out a subjective well-being assessment with respect to inequalities or justice.

2.4.2 Inequality and justice

The reviewed papers directly or indirectly analyzed possible sources of inequality: costs, proximity to certain infrastructure, differences in age and gender, and technological literacy. These factors indicate some potential positive and negative impacts of MaaS. When MaaS adoption is limited by high prices, unfair competition with private vehicles, or technological barriers, any existing inequalities in transport are carried into the new solution and deserve attention.

Beyond the problem of being able to access MaaS as a transport solution, inequalities arise from the ability to physically access the system. The reviewed studies lack clarity regarding the accessibility potential associated with MaaS. Qualitative results say too little about improved conditions for users seeking to reach their destination, and quantitative results do not specify a time or any other formal indicators of accessibility gains. On the other hand, reduced costs are noted for both end users and the public sector, which can be seen as an accessibility gain. The evaluation of accessibility loss and gains remains a gap in the literature that MaaS-oriented trials have not addressed. This observation applies to both objective (time, cost, distance) and subjective (comfort, security, safety, etc.) measures that should be applied to potential inequality criteria among the social groups discussed.

One of the reasons for the lack of STIs assessments could be that four of the 20 trials were analyzed from the operator's perspective, where the main goal is to design a profitable service. However, it is precisely in these cases that public organizations should intervene and guarantee that MaaS implementation is aligned with societal goals and reduced STIs.

Finally, while the goal of this review was not to assess accessibility per se, the reported trials could be a potential data source for a comprehensive accessibility analysis and estimate of impacts on STIs. The results of such a study could become a tool for researchers and practitioners worldwide who must make decisions about MaaS design, implementation, and governance.

2.5 Discussion and conclusions

This paper sought to explore three aspects of MaaS. The first is their structure. Although the theory is presented in hundreds of papers, the concept only becomes tangible when MaaS schemes are implemented in practice. RWA applications show the actual appearance of MaaS, reshaping the abstract concept to align with practical constraints. The second relates to transport inequality and inequity, which, although widely discussed in the literature, is rarely linked to MaaS. This review presented a way to evaluate MaaS schemes with respect to four components of equity through the ROOW approach.

The third aspect refers to how existing MaaS schemes address STIs, which are rarely discussed in the literature. This review found that, from an RWA point of view, little is known about the impact of MaaS on STIs. After filtering out theoretical and conceptual works, only 20 RWA-based papers remained. Of these, only two directly considered the implications for equity or accessibility (although it should be noted that they were not based on full MaaS trials).

After applying the ROOW analytical framework, MaaS might have both desirable and undesirable impacts on STIs. On the positive side, MaaS schemes provide access to new modes that would otherwise be hidden from users and may serve as a solution for both rural/low-density areas and health/social care-related trips, by providing on-demand services. On the negative side, MaaS is perceived as expensive; hence, it is a barrier for low-income people.

The latter, together with the need to be digitally literate, could generate social exclusion. Furthermore, there are equity issues, such as limited internet access, limited geographical coverage, or prohibitive entry prices. Finally, the legal framework may hinder private-public collaboration. In this context, institutional design is crucial to mitigate any negative effects of MaaS on STI; in particular, spatial injustice could emerge if transport authorities only serve areas where there is strong civic support (e.g., a coherent and well-funded public organization).

The analysis found that the reviewed papers did not measure the social benefits that MaaS could provide. None of the case studies presented a clear policy to incentivize the adoption of transport modes that are aligned with collective values such as environmental sustainability or equity. Some schemes included PT as one of a range of options, which, in other circumstances, might have been rejected by more car-oriented users. However, this alone is not enough to classify a scheme as aligned with broad social values. Leaving the final decision of whether to use (or not) a more sustainable option to an end user who is under market pressure cannot be seen as a societal-value- oriented approach.

The main advantage of the private car over public transport is its flexibility versus the rigidity of the latter regarding routes, coverage, and schedules. MaaS has the potential to provide flexibility to public transportation travel, as the integration of several transport modes that MaaS encompasses allows overcoming well-known issues such as limited coverage, delays, uncertainty (lack of real-time information), and even scheduling associated with public transport. For instance, MaaS offers the possibility of Demand Responsive Transport for transit-deprived or low-demand zones, as well as a white label API, marketing, app development, and technical support. A concrete example of this is the case of the SHOTL service in the Scottish Highlands, which allowed smart city technology in a rural area, improving the level of service and even reducing operational costs.

I argue that MaaS should not be seen solely as a solution to reduce private car trips, but rather as a means to improve accessibility of non-car users, and as a tool for public authorities to enhance and (re)gain control of urban mobility by exploiting its potential. More studies on this end are needed to assess how these innovations would impact equity, considering not only the horizontal but the vertical cost of their implementation.

Turning to opportunities to improve MaaS, there is a need for well-funded public awareness campaigns, as their absence directly impacts accessibility. The potential use of MaaS to move goods and for companies to provide MaaS subscriptions to their employees should also be assessed. From the operator's perspective, trust is essential for data sharing between stakeholders, and MaaS solutions should be context-specific rather than one-size-fits-all. However, given that most MaaS systems are run by for-profit companies, it is unrealistic to expect the private sector to ensure public services and provide equitable mobility services to all populations. Only time will tell if the MaaS models offered by private companies are aligned with governmental objectives such as limiting car usage and providing an improved PT infrastructure with fewer subsidies.

The literature on the broader implications of STIs for MaaS governance remains underdeveloped, and this gap has been repeatedly highlighted in recent publications (Audouin & Finger, 2018; Butler et al., 2021; Pangbourne et al., 2020; Singh, 2020; Smith & Hensher, 2020). MaaS implementations will challenge governance and policy frameworks in new ways. This review highlights that, at the present time, most MaaS schemes are focused on questions of viability, whether people are willing to pay for the service, and whether demand will increase. Hence, the intervention of public authorities is mandatory to guarantee transport justice.

The ROOW approach gives us some hints on how to move forward. From a ROOW perspective, MaaS schemes contain at least three factors that may drive exclusion, each reflecting a distinct tier of inequality. People may be excluded from entering the system due to: (1) a lack of basic resources; (2) not being covered by the system's supply infrastructure; or (3) simply not benefiting from its intended positive results. Each of these factors may be unequally distributed across societal and economic groups (social inequality) or geographical areas (territorial inequality), which denies the possibility of an equitable service. Another potential dimension, which is not discussed in the reviewed papers, concerns disparities between generations, reflecting a time-based inequality that is closer to the concept of sustainability.

Given the early stages of MaaS development, the cases analyzed were mostly pilots or small-scale interventions, limiting findings to the current state of the art, which could be steered in the future, considering the rapid evolution of the MaaS concept and systems (as I hope and expect this research to help with). If the user's accessibility is not prioritized, STIs will most likely increase because of MaaS implementation.

Future work should clarify how public authorities could intervene and what role they should play in MaaS implementation, operation, and governance. For instance, transport authorities need a transformation to be able to handle the management of mobility databases and platforms so they can enforce an open-data policy for operators and serve as a trusted third party while holding control of the users' information. Also, they need to be able to assess whether new mobility services or technologies contribute to the city's transportation policy objectives before providing support.

It would also be interesting to investigate stakeholders' awareness of STIs and their ability to guarantee mobility services in deprived or low-demand areas. With the correct approach, MaaS could be used to both successfully fill transit deserts and reduce inequality. Four basic questions should be raised: who will or is planning the system? Operating it? Financing it? And how will inhabitants benefit from it?

Finally, the literature lacks a comprehensive method to assess MaaS systems. Current integration-level approaches preclude comparisons or rankings given their incremental perspective. This could be achieved by considering the different interaction opportunities between players. Interactions between players may occur via several elements (Information on transport operations, Multimodal networks, Booking/ticketing solution, Integrated payment, stakeholders' cooperation, Bundling/subscriptions, and Incentives to achieve societal goals (Ho et al., 2018; Lyons et al., 2019; Sochor et al., 2018). For a robust solution, MaaS schemes should encompass these elements in their solutions. The more interactions they facilitate, the higher the integration level should be.

Chapter 3. Refocusing MaaS discussion: a brief

This chapter was published as a journal article: Orozco-Fontalvo, M., Moura, F., 2023. Refocusing MaaS approach: A brief. Transport Policy 141, 340–342. https://doi.org/10.1016/j.tranpol.2023.08.002

Summary

Building on the systematic review conducted in Chapter 2, this chapter aims to highlight the importance of refocusing the discussion around MaaS potential by arguing that it should be considered a powerful tool for public authorities to steer and optimize urban transport networks rather than a means to reduce car ownership only. This discussion is relevant given the rising number of MaaS skeptics and people losing faith in the concept. This approach is based on the possible accessibility gains and the equity impacts it could bring regarding, for instance, the global south and the gender gap in transport.

3.1 Introduction

In recent years, several studies that aimed at reducing private car usage as the primary goal (Christensen et al., 2022; Hensher et al., 2021; Hensher & Hietanen, 2022) have raised concerns regarding the ability of mobility as a service (MaaS) to reduce car ownership. These studies suggest that investing in MaaS platforms is pointless if they do not offer the right incentives for users to give up their cars or make MaaS attractive so they could use it as a complementary service. The first paper about Mobility as a Feature (MaaF) (Hensher and Hietanen, 2022) explains how insurance companies could be the brokers for MaaF, so car owners would join, an interesting and probably successful measure to make MaaS a reality, but what about non-car users?, We could include them by offering mobility packages through other services, such as bicycle insurance, life insurance for pedestrians, etc., so it can reach the whole population.

In an interview with Mobility Payments last year, Professor David Hensher stated that “MaaS is in danger of becoming a hyped socio-technical phenomenon lacking full-scale implementations” and that “MaaS will only have a future if it changes the travel behavior of a sufficient number of people.” I agree with these statements and believe that while reducing car usage is highly relevant and acknowledging that it was the argument that created the MaaS concept, efforts should highlight the importance of other potential outcomes (Butler et al., 2021c). The research question would then be: ***Is there an alternative approach to make MaaS feasible?***

Some studies found in the literature argue that MaaS could eventually change travel behavior by improving the commute of non-car users, who will refrain from joining the car culture (Strömberg et al., 2018) and possibly influence other people (including car users) to join MaaS. Such an argument finds its conceptual basis in the Social Influence dimension included in the extension of the Technology Acceptance Model (Venkatesh and Davis, 2000). MaaS could also capture additional trips from car users and increase opportunities and welfare by, for instance, allowing them to take a shared bike to the gym.

3.2 Structural Barriers and the Limits of MaaS

I concur with the studies above that MaaS cannot compete directly with the private car because it will hardly match attributes such as privacy, comfort, and a "sense of freedom" (Jittrapirom et al., 2020). Moreover, MaaS cannot control or address the main factors behind car ownership: the built environment and urban policies (and politics) (Ding and Cao, 2019; Wang et al., 2018). MaaS (by itself) is not the solution to having fewer cars on the streets but rather a complementary measure along with other effective interventions (Kuss and Nicholas, 2022). Competing with the car (although not only) would require strong incentives beyond the financial approach (Hensher, 2022).

If we consider MaaS's primary objective as increasing the level of accessibility to all segments of the population, then maybe the primary goal should not always be to reduce car ownership (Hensher et al., 2022; Mulley et al., 2023). Instead, MaaS could be a valuable tool for public authorities to enhance the reliability and level of service of current public transportation systems and, in some cases, even regain control of the network where there is a high share of informal modes. With this approach, we can create an integrated transportation network that caters to the diverse needs of all individuals, regardless of their vehicle ownership (Lajas and Macário, 2020). Also, Ho (2022) states that "combining services across multiple modes in the most effective way possible can affect mode choice but also trip generation," which means MaaS can help users meet the latent demand through sustainable modes.

Using a multilevel perspective approach (Geels, 2012), an analytical framework for socio-technical transitions that suggests that innovation occurs across three levels of analysis (Landscape, Regime, and Niche), we can identify that the main barriers to MaaS adoption are the current *stabilizers* of the landscape (such as the built environment and car culture) and the *lock-up* mechanisms of the regime (policies favoring the car, disagreements among operators, aspirational status & lifestyle, users preference, etc.). Being MaaS a Niche innovation, it can't (and should not) be responsible for reducing car ownership without addressing these practices.

3.3 Equity, Access, and the Role of Public Authorities

On the bright side, there are encouraging *destabilizers* of the landscape and *cracks* in the regime that are reducing car ownership and are not directly linked to MaaS. For instance, the younger generation's aversion or disinterest in owning a car or even a driving license, which according to *"Throughout the rich world, the young are falling out of love with cars"* (2023*),* them is mainly related to the growing environmental awareness and the existence of mobility platforms such as Uber or Lyft, given their ability to use and adapt quickly to technology (Jittrapirom et al., 2017). This trend will continue in the following decades, bolstered by adopting "smart growth policies" to make cities more livable (Zhong and Lee, 2017). Also, cycling and walking already account for 40% of all European urban trips, with Bulgaria, Romania, and Spain having a higher modal share for these modes than for cars (European Commission, 2022).

Jittrapirom et al. (2020) stated that switching from cars to MaaS may be marginal. As such, rather than focusing on reducing car ownership, which might be an unattainable goal for MaaS, our attention should be on using MaaS to make public transport and shared mobility services more attractive to new generations and avoid them adopting the car culture. Ditching MaaS based on its inability to reduce car ownership is also inequitable (Pereira et al., 2017). MaaS features have the potential to provide access to transit-deprived areas and to those who cannot afford a car or drive one, such as elderly or disabled individuals. MaaS can optimize and reorganize the network according to the modes included (e.g., using ride-hailing as TOD in specific areas if financially suitable), enabling access to opportunities disregarding car ownership.

Also, the "shift from the car approach" may ignore the situation in the global south, where in most cities, public transport or informal modes dominate modal shares (Hasselwander and Bigotte, 2022). In addition, women worldwide have less access to cars, different travel patterns, and make more chain trips than men, meaning MaaS could also play an essential role in reducing the gender gap in transport and increasing accessibility for women (Loubser et al., 2021; Ng and Acker, 2018; Qiao and Yeh, 2021; Scheiner and Holz-Rau, 2017; Tiikkaja and Liimatainen, 2021). However, my aim is not to stigmatize the car as it can be instrumental in the rural context, but to start considering the different segments of the population, their needs, resources, and travel patterns in the design and implementation of new mobility services.

In this sense, public authorities should lead or enable MaaS systems to ensure that their social benefits support the required investment level and avoid the concerns raised by Jittrapirom et al. (2020) that they will compete with public transport.

3.4 From Concept to Implementation: A Strategic Approach to MaaS Evaluation

A well-implemented, fully integrated MaaS system could prevent those who have never owned a private car from starting to own one, and this could have a direct impact on sustainable goals in the long term. However, as Hensher & Hietanen (2022) state, "We have seen almost no government commitment to subsidizing MaaS beyond what they already do for regular public transport except Japan." I believe that MaaS could empower the public transport and land use strategy, as it can be used to improve the transport network, accessibility, and sustainability in many cities worldwide, becoming the cornerstone for strategic change.

If researchers and policymakers focus not mainly on private car users but include current public transportation and sustainable modes users creating a set of KPIs that align with the societal goals (Hensher et al., 2023), the task would be potentially easier and more realistic to achieve, positioning MaaS not as an alternative to the private car but as a digital tool that helps us achieve more comprehensive societal outcomes such as decarbonization, improved equity, and accessibility for all. This way, reducing car ownership could be a consequence rather than the objective of MaaS globalization.

This KPIs set could become a benchmark for assessing MaaS systems performance and should include for instance: reduced private vehicle ownership, effective and active accessibility gains (Vale, 2020; Vale et al., 2015a), reduced VKT per capita, shared modes trips increase, gender gap impact (McIlroy, 2023), increased trip awareness and improved social equity (Butler et al., 2021c). This would provide a more holistic approach towards MaaS.

3.5 Conclusion

Specific research should be conducted to correctly define context-specific KPIs, as the transportation, land-use system, legal, and institutional settings differ between countries (Hensher et al., 2023).

As MaaF could make MaaS financially viable for private companies, public authorities must understand that subsidizing or supporting MaaS initiatives could generate a strategic change and steer the path to achieving mobility-related societal goals. This said, MaaS (or MaaF) stakeholders should move on beyond talking about it (Hietanen, 2023) and speed up its implementation, given that, as explained in this brief, there are strong reasons to support it rather than ditch it and start exploring other market segments.

Finally, if the ultimate goal is to reduce car ownership, maybe policymakers should stop with the carrots (and not treat MaaS as one) and start getting serious about the sticks, for instance, road pricing, which has been difficult to implement in most countries due to the political regime.

Chapter 4. IMPReSS: A comprehensive method to classify MaaS systems from an equity perspective

This chapter was partially published as a journal article: Orozco-Fontalvo, M., Soares Lopes, A., Vale, D., Moura, F., 2024b. Impress: A comprehensive method to classify maas systems. Transport Policy 155, 234–241. URL: https://linkinghub.elsevier.com/retrieve/pii/S0967070X24002014, doi:10.1016/ j.tranpol.2024.07.005.

Summary

As mentioned in previous chapters, there is no comprehensive way to compare or classify MaaS systems from an equity perspective. In this chapter, the IMPReSS method is introduced, a binary coding approach that assesses several dimensions of MaaS: Information, Multimodality, Payment, Reservation, Subscription, and Societal goals. It allows proper classification and comparison of different systems, using the societal goals as a cornerstone for its evaluation. Also, a complementary scoring system based on the IMPReSS topology is presented. This qualitative and quantitative methodology will allow practitioners and researchers to characterize, identify, and adequately assess transportation services and their potential to become a fully integrated MaaS system. The results show that mature MaaS systems with public authorities involved, and some often excluded from MaaS discussion systems, are ranked higher. In summary, it assesses systems from a different and flexible perspective when compared to existing classification systems.

4.1 Introduction

According to the literature, the basic features for an integrated multimodal system to be considered MaaS are clear: “multiple modes of transport (public and private), one single application, user-oriented approach, mobility packages, real-time information, multimodal journey planner, and payment integration” (Arias-Molinares and García-Palomares, 2020b). Several authors (Arias-Molinares and García-Palomares, 2020b; Jittrapirom et al., 2017; Sochor et al., 2018a) have already studied the definition and scheme of MaaS. Nonetheless, the impacts of MaaS on mobility and accessibility are yet to be thoroughly analyzed, and its concept is still evolving (Lopes et al., 2023).

Several classifications have been proposed to classify MaaS systems, allowing for the differentiation between complete and partial MaaS systems. The first, proposed by Kamargiani (2015), consisted of six incremental levels (regarding the features included): cooperation, integration of ticketing, payment, ICT, and tailored mobility packages. This scheme evolved into the topology proposed by Sochor et al. (2018a) and is based on levels of integration to allow a “comparison” of different services and integrate the societal goals in the discussion. It is considered *“0, in case of no integration; 1, integration of information; 2, integration of booking and payment; 3, integration of service offer subscription; and 4, integration of societal goals”*(Sochor et al., 2018a). Based on this work, other authors proposed different methodologies or scales to qualify MaaS systems, adopting different perspectives and with different objectives (Bandeira et al., 2022; Ho et al., 2021; Lyons et al., 2019).

However, the incremental nature of these classifications limits the ability to correctly identify a system's characteristics solely by its "level of integration." For instance, according to Sochor (2018a), a level 4 classification would imply that such a system encompasses all the characteristics of lower levels, which is not always the case. Furthermore, the proposed methods that aim to break with this echeloned classification (Bandeira et al., 2022) still assign the same weight to all assessed dimensions. Therefore, there is a gap in how to assess, classify, and compare mobility services. How do the current classification methods fit the concept of MaaS?, given that the MaaS label should probably only be used to describe a fully integrated and sustainable system rather than just an enhanced travel planning app (Hensher et al., 2021b). Therefore, this Chapter aims to propose a comprehensive classification method (designated IMPReSS) for comparison, classification, and clear identification of the characteristics of mobility services while addressing the main dimensions that compose the MaaS concept without the constraints of the bottom-up (incremental) approach.

To reach this objective, Section 2 presents the concept of MaaS and the existing classification schemes and topologies, highlighting their main shortcomings. Section 3 describes the proposed classification method. In Section 4, this proposal is applied to a few selected systems from different countries for illustration purposes. Section 5 discusses the findings, and Section 6 draws the main conclusions of the research.

4.2 Literature review

While only a few fully integrated MaaS systems operate, several systems or platforms could be considered early or partial forms of MaaS. In general, these 'partial' MaaS systems offer some but not all the previously mentioned features and, as such, cannot be considered a complete MaaS system. Two well-known examples are Uber and Google Maps. Uber is a platform that allows users to plan, book, reserve, pay for, and access mobility services, but it is not multimodal nor integrated with other mobility services. Google Maps provides information and trip planning services, but lacks other necessary features such as payment integration, mobility packages, etc.

In this sense, several authors have defined classification methods to characterize existing transportation systems regarding MaaS services' integration levels (Table 6). Five aspects are usually included in these systems: information access, multimodality, vehicle availability, payment and booking processes that facilitate access, and the contribution of the existing system to societal goals. All these aspects are assessed in terms of their seamless integration into the proposed service.

Table 6. Current propositions for MaaS integration levels characterization

Level	Sochor et al (2018)	Ho et al. (2021)	Lyons et al. (2019)
5	N.A.	N.A.	Full integration under all conditions: Full operational, informational, and transactional integration for all journeys
4	Societal goals integration: Policies, incentives, etc.	Societal goals integration: Policies, incentives, etc.	Full integration under certain conditions: Not all modal combinations available offer a fully integrated experience
3	Service offer integration: Contracts, bundles, subscription, etc.	Service offer integration: Contracts, bundles, subscription, etc.	Partial integration: some journeys offer a fully integrated experience
2	Integration of booking & payment: Single trip-find, book, and pay	Booking integration: No integration, public linking, deep linking, API integration Payment integration: Single to all providers, single to monthly trip	Limited integration: Informational integration across some modes with operation integration
1	Information Integration: Multimodal travel planner, price info	information integration: Multimodal travel planner, price info	Basic integration: Informational integration across (some) modes

Level	Sochor et al (2018)	Ho et al. (2021)	Lyons et al. (2019)
0	No integration: single separate services	No integration: single separate services	No integration: No info on operations or transactional integration across modes

Following the initial proposed MaaS classification (Kamargianni, 2015), several authors have presented new approaches to help characterize transportation systems in terms of MaaS service integration levels. Sochor et al. (2018a) identified four incremental levels and proposed the (to date) most known MaaS topology, encompassing the integration of information, booking, and payment, bundle services, and societal values (Table 6). Ho et al. (2021) adopted and extended this topology by dividing level 2 (booking and payment) into two independent levels. These authors recognize that the primary limitation of existing MaaS initiatives is primarily related to the highest level of integration, specifically the integration of societal goals.

Alternatively, Lyons et al. (2019) interpreted integration from users' perspectives in terms of cognitive effort. They proposed a topological classification with five levels, with a bottom-up approach, starting from no integration and advancing with the integration of operational information, multimodal information, integration to limited modes, integration to all modes in certain circumstances, and integration to all modes under all circumstances. In other efforts found in the literature, Arias-Molinares et al. (2022) analyzed the different functions or characteristics of different “emerging” MaaS systems worldwide. However, the systems are neither compared nor ranked because of the lack of a comprehensive methodology. Also, they do not consider the systems’ societal impact (Lopes et al., 2023). This hinders the ability to identify the characteristics and “completeness” of the mobility services.

These approaches are examples of characterization and classification attempts of MaaS integration levels, but they have limitations. For instance, they rely on incremental and ordinal logic. For example, it is unclear what a level 4 MaaS system means. Does a MaaS system, considering societal goals (level

4), encompass all other levels? If so, to what extent? Indeed, this hierarchical perspective hinders its ability to correctly assess systems with characteristics belonging to the higher levels but missing some of the lower ones. Certainly, a system may lack one of the fundamental characteristics (i.e., route information) while incorporating full multimodality integration: most cities' PT cards that include train, ferry, bikes, buses, and metro tickets are good examples. Another example is Uber, which allows for single-trip booking and payment but has no multimodal planner.

Generally, these topological frameworks provide helpful information about the system and an overview of its development stage or integration level. However, Bandeira et al. (2022) state that the current MaaS integration levels neglect essential dimensions such as geographic coverage and contributions to sustainability. They propose six integration categories: environmental policy, social cohesion, personalization, IT integration, multimodality, and geographic area. The proposed methodology rates each category from 0 to 5 to provide a final score based on their sum, up to 30 points. However, while addressing the limitation of the hierarchical approach, this scoring method weights all dimensions equally, which implies a new limitation, as it does not prioritize certain features, such as societal goals, for scoring purposes.

Moreover, the proposed numerical final scores are still hard to interpret, permitting only the numerical comparison between levels. This means that the number representing the level, or score, does not give information about the MaaS-like system’s integration characteristics other than their position in a list, nor which category (or categories) is responsible for the final score. When these two limitations are combined, the result is a list that may categorize diverse mobility services as being at the same level, providing a misleading impression of homogeneity but not a straightforward way to assess or fix any discrepancies. Then I pose the question: ***How can we compare MaaS systems and identify their level of integration?***

At least three gaps were identified by evaluating existing classification schemes and topologies. First, there is an informational gap, where schemes fail to inform the reader which characteristics belong to the classification method. Second, a cumulative gap when schemes assume that lower-level features are necessarily included in high-level ranked systems. Finally, a relevance gap, where assessment schemes ignore that specific dimensions of MaaS systems are more or less relevant than others.

4.3 Classification method

One of MaaS's main objectives is to allow individuals to access relevant opportunities without the need to own a means of transport, thereby transforming mobility into a service that can be used whenever needed. Therefore, accessibility should be a key indicator when assessing a MaaS system. Hence, a binary topology is proposed, which aims to classify any MaaS and MaaS-like *platforms* by scoring and ranking the system based on its features, dividing them into six features. These were defined based on the literature (Esztergár-Kiss et al., 2020; Ho et al., 2021; Kriswardhana and Esztergár-Kiss, 2023a; Storme et al., 2021) but placed in an specific order related from the most simple to the most complex feature: (I) Information access, (M) Multimodal options included in the system, (P) Payment within the app (seamless), (Re) booking or Reservation capabilities, (S) Service subscriptions, and its association with (S) Societal goals and values. The classification method was named after its features' initials: IMPReSS.

For simplicity, a Boolean classification awards 1 or 0 to each category, whether the system includes the corresponding features. The symbology representing the classification is a binary sequence of six digits. Each position represents a feature rendering values between 000000, meaning a "zero" MaaS system, and 111111 for a full MaaS. This approach fills the gaps presented in 4.2, as it clearly informs the reader which feature is available or missing on each system; it is not cumulative, as having a higher-ranked feature does not imply that lower ones are included; and it allocates a different weight to each feature depending on its position within the binary chain.

The sequence of the features within IMPReSS was defined in ascending order of implementation complexity and systemic relevance; the further to the right, the more its implementation is complex, and its systemic relevance increases. First, the most common and widely available feature among mobility apps is the provision of (I) information about transport supply, such as departure times, stops, charging stations, etc., and trip planning suggestions. In the second position, the integration of (M) multimodal networks, which considers the number of modes available, followed by the option of (P) paying for (individual) services with the app.

The fourth position refers to the possibility of (Re) reservation and booking different modes, including on-demand transport. Next, the availability of bundles or (S) subscriptions, given the complexity of agreeing on margins and fees with the different providers and integrating subsidized and market-driven services in the same package, which also requires to consider city specific conditions or even tailored bundles based on the travel patterns (Esztergár-Kiss and Kerényi, 2020; Kriswardhana and Esztergár-Kiss, 2023a), it is assumed that if the system offers bundling options it means that it has already solved the contracting, tariffs and fees issues with the operators involved. Finally, whether the system contributes to achieving transport-related (S) societal goals, which is simultaneously the most systemically relevant feature and complex to implement. The method proposed aims to classify any MaaS and partial MaaS systems according to their features.

Table 7 presents a practical guide or criteria for coding each feature. With a question for each feature for which a positive answer awards '1' (True) or '0' (False) for a negative reply. For the multimodal category, public transport was included as a requirement for awarding "1". Accordingly, Hensher et al. (2020, p. 6) state that *"if public transport is to be at the heart of MaaS, then we need to create circumstances where it is natural for public transport to seamlessly integrate with first and last mile solutions."*

According to IMPReSS, a full MaaS system would be a platform that provides real-time user information and multimodal trip planning options: seamless booking; unified payment; integrated ticketing; within a collaborative environment between public and private actors; and active commitment towards societal and collective agendas. The classification system proposed aims to score the systems based on their capabilities, but does not address their performance. Hence, the user experience or satisfaction is not being considered, which is discussed further in a later section.

Table 7. Features description

Complexity	Question	Feature	Icon
1	Does it include a multimodal planner?	INFORMATION ACCESS	
2	Does it includes PT + other services?	MULTIMODAL OPTIONS	
3	Is it possible to pay within the app?	EASY PAYMENT	
4	Is it possible to Book within the app?	ReBOOKING SERVATION	
5	Does it offer more than one subscription option?	SERVICE SUBSCRIPTION	
6	Does it integrates societal goals?	SOCIAL GOALS AND VALUES	

Additionally, this ordered notation allows us to easily identify what is missing and what's not by just looking at the binary sequence. For instance, a 111010 system means that the platform lacks *payment* in the digital platform (hereafter referred to as 'app') and that there is no involvement of the public authority Table 8. This qualitative approach has the potential to become a powerful planning tool as it highlights what systems need to become a full MaaS.

Table 8. IMPReSS notation

Information access	**Multimodal options**	**Payment (Seamless)**	**booking or Reservation**	**Service subscription**	**Societal goals and values**
1 (included)	1 (included)	1 (Included)	0 (absent)	1 (included)	0 (absent)

The closer a system is to a full-MaaS (111111), the better it will provide a comfortable and equitable mobility service to the user. It could be used by different stakeholders to identify exactly what is missing or not on each system. Also, independent organizations could use it as a benchmark. It can tell cities how close they are to a full-MaaS and possibly to meet the expectations of their transport policy goals

(Chapter 3), or simply used by users to choose the most convenient option. For easier interpretation, an infographic was created Figure 6, grayed out items indicate the absence of the feature, while colored items indicate the opposite.

Figure 6. IMPReSS infographic

Information access	Multimodal options	Payment (Seamless)	booking or Reservation	Service subscription	Societal goals and values
1 (included)	1 (included)	1 (Included)	0 (absent)	1 (included)	0 (absent)

4.4 Preliminary completeness score proposal

As one of the flaws found in the current MaaS topologies is related to the impossibility of comparing different systems, a preliminary "completeness score" is proposed to be able to do this directly. Note that the qualitative classification (i.e., the binary chain) is the essential aspect of IMPReSS, allowing for the immediate identification of which of the six essential MaaS features are present or absent. This proposal is a complementary step for IMPReSS, which harnesses the order of complexity of the binary chain to our advantage. It is based on the idea that each system has a different level of completeness towards a full MaaS, and that some dimensions are more "important" than others, as explained in the previous section.

After applying the IMPReSS scheme, we convert the binary sequence into a decimal number using its positional notation. We must multiply each bit by its corresponding power of 2 and then sum up the results. Starting from the rightmost bit, the mathematical equation for this conversion is:

$$IMPReSS_{decimal} = (i \cdot 2^0 + m \cdot 2^1 + p \cdot 2^2 + re \cdot 2^3 + s_1 \cdot 2^4 + s_2 \cdot 2^5) \text{ Eq.1}$$

, where *i* is 1 or 0 if Information features are included in the MaaS system or not,

m is 1 or 0 if Multimodality features are included or not,

p is 1 or 0 if Payment features are included or not.

re is 1 or 0 if Reservation or Booking features are included, or not.

s_1 is 1 or 0 if Subscription Services (bundling) features are included or not, and

s_2 is 1 or 0 if Societal goals features are included or not.

To increase the ranking's intelligibility, we normalize the IMPReSS decimal by dividing by 63 the maximum possible IMPReSS score for the full-MaaS system, i.e., 111111. The IMPReSS score (I_S) indicates a MaaS completeness level calculated by Eq.2.

$$I_s = \frac{(i \cdot 2^0 + m \cdot 2^1 + p \cdot 2^2 + re \cdot 2^3 + s_1 \cdot 2^4 + s_2 \cdot 2^5)}{63} \text{ Eq.2}$$

As an example, if a system obtains an 011100 IMPReSS score, it means it lacks (I) in-app user information, but provides (M) multimodal services, (P) in-app seamless payment options, and (Re) the possibility to book a ticket. Still, it does not offer (S) service bundles, such as subscriptions, and is not aligned with (S) collective and societal goals. For scoring and ranking, the binary sequence is converted into decimals (001110 = 14) for a final score or position of 14/63, or 22.2% of a "full MaaS system."

This proposal main limitation is that it needs validation to adequately define the weights of each dimension, but it is presented to highlight the importance of allowing comparison between systems and second as an invitation for other researchers to further explore this assessment or a different approach, for instance a linear combination of weighted dimensions that be calibrated with a multicriteria approach validated by stakeholders and experts.

4.5 Results

To demonstrate the usefulness of IMPReSS, it was applied along with other classification schemes (see section 2) to MaaS platforms or “emerging” MaaS systems currently operating in different countries and compared the results. The application of IMPReSS enables greater flexibility in describing the functionalities of MaaS systems. In some cases, it has no benefits compared to other ranking schemes. However, there are cases in which functionalities are not cumulative, and the proposed method presents some advantages. In this sense, a few operational transport integration solutions, or MaaS-like systems, worldwide were selected to illustrate the application of the IMPReSS MaaS classification system.

4.5.1 Comparing IMPReSS to other schemes.

4.5.1.1 UbiGo (Stockholm)

An example of a MaaS system to which IMPReSS brings limited benefits is the Swedish UbiGo service. The UbiGo was a MaaS initiative that started in Stockholm (Sweden). It offers a routing app with multiple transport modes (bus, metro, train, carsharing, rental, and taxi), an in-app payment and booking system, and mobility packages and subscriptions that permit limited personalization. There are no integrated incentives for customers to align with environmental or societal goals. According to Sochor et al. (2018a) integration levels, UbiGo scores 3/5 (Table 9), 4/4 according to Lyons et al. (2019) scale, and 15/30 (overall 0.50) according to Bandeira et al. (2022). Finally, the IMPReSS classification is 111110.

In this example, IMPReSS clarifies which features are encompassed by UbiGo, or not, i.e., it does not include societal goals. Also, IMPReSS performs better at spotting more easily where the gap is. Conversely, it does not add value in identifying gaps in the hierarchical nature of other classification systems (hereafter referred to as a “Hierarchical gap”), as there are no missing in-between features.

4.5.1.2 Uber (International)

Uber is an international app-based mobility giant that offers point-to-point routing solutions with integrated payment and seamless booking. It operates in dozens of countries, covering both rural and urban settings, but is limited to unimodal routes based on a selection of motorized private vehicles, including privately hired rides, ride-sharing options, e-scooters, and bikes (in some countries). This MaaS-like system does not provide any incentives toward societal or environmental goals.

Uber's setting is sufficiently complex, and Sochor/Ho and Lyons' classification methods do not classify this MaaS operator adequately due to its "Hierarchical gap." Bandeira's system scores Uber as 4.1.3.3.2.1(0.46), clearly stating the important geographic dimension of Uber and its weak multimodality capability and lack of societal and environmental engagement. The IMPReSS classification is 001100, highlighting Uber's limitations regarding multimodality, even though the system allows in-app payments, reservations, and supplies customers with some mobility packages (limited to the supported transport modes).

4.5.1.3 Navegante (Lisbon)

Lisbon's transit card, Navegante, provides access to all public transport modes with a single smartcard (including bike-sharing, buses, trains, trams, metro, and ferries), offering pay-as-you-go, daily tickets, and monthly subscriptions for an affordable price. It also provides free rides for students under 25 and elders (over 65), and it is aligned with the policies of the "Transporte Metropolitano de Lisboa," the public transport authority of the city. However, it does not provide *in-app* user information (such as trip planning) or booking solutions.

IMPReSS classification would be 010011, while it would score an inconclusive score or even a zero, according to Sochor/Ho. Navegante has a clear societal orientation (which translates into a Sochor 4 score) while lacking basic dimensions, such as supply or routing information and booking capability. Lyons' score is also inconclusive (approximately 2) since it provides limited integration across some modes with operation integration but lacks all informational aspects. Bandeira would score Navegante

2.3.2.1.1.5(0.46). Importantly, Bandeira's scores for Navegante and Uber are similar (both at 0.46) but have very different characteristics, with Navegante being more sustainable and equitable.

4.5.1.3 LexyPass Helsinki

Another illustrative case is the Helsinki LexyPass service, which provided (in November of 2021) a real-time routing app that covers the region of Helsinki with limited modal combinations (only public transport) and allows for single-trip payments and booking. The system claims to promote diminished sustainable footprints. Still, no active engagement solution exists (other than the customer's intention to use public transport included in the MaaS system).

The scores for both Sochor/Ho and Lyons' classification systems are also complex due to the non-hierarchical nature of MaaS features. They would both rank LexyPass in level 2. Due to its lack of societal goals integration and its impossibility of connecting customers and service operators via bundles or subscriptions (the two most relevant dimensions), IMPReSS classification for LexyPass is 101100.

4.5.1.4 Summary

IMPReSS brings a better understanding of all MaaS capabilities, as it clearly states the hierarchical gaps among the features addressed, which are unclear in Sochor/Ho and Lyons' classification systems. It also explicitly includes the relative relevance of MaaS features. Also, IMPReSS is more transparent on whether MaaS-like systems integrate seamlessly with societal goals (e.g., incentives to choose active mobility over motorized, full geographical coverage, or discounts to socially excluded groups and minorities, etc.) and therefore are more complex and advanced.

Among the selected systems (Table 9), Navegante seems the most complete because of its alignment with societal goals (including economically disadvantaged groups and exclusive incentives towards public transport usage), even though it was not even considered in the existing topologies. This method allows us to identify that Navegante has the most complex features, and it would be quite simple for it to become a full MaaS just by adding information, payment, and reservation.

Table 9. Comparing existing MaaS topologies with IMPReS

		Sochor/Ho	Lyons	Bandeira	IMPReSS
MaaS-like system	UbiGo (Gothenburg)	3	4	2.4.5.2.1.1(0.50)	111110
	Uber	**1** (+ lv 2, 3 items)	**2** (+ lv 3 items)	4.1.3.3.2.1(0.46)	001100
	Navegante (Lisbon)	**0** (Lacks lvs 1, 2)	**2** (Lacks lvs 1, 2)	2.3.2.1.1.5(0.46)	010011
	LexyPass (Helsinki)	**2** (Not multimodal)	2	1.3.3.1.1.1(0.33)	101100

Note: "lv" stands for level.

4.5.2 Application of the ranking system

To illustrate the flexibility of this ranking proposition, 20 MaaS-like transport systems worldwide were classified. The results are presented in Table 10. As expected, companies that have all the assessed features are ranked first, followed by the ones with local or national policies integrated in the system (societal goals). This ranking clearly favors companies with more complex features.

Table 10 MaaS-oriented transport systems currently operating (non-exhaustive list)

MaaS	Country	City	IMPReSS	Decimal	Completeness
Umaji	Taiwan	Taipei	111111	63	100%
Whim	Finland	Helsinki	111111	63	100%
Wikimove	Germany	Bamberg	111111	63	100%
Jelbi	Germany	Berlin	111111	63	100%

MaaS	Country	City	IMPReSS	Decimal	Completeness
ZUM	Spain	Zaragoza	111111	63	100%
Transport for London	England	London	111011	55	87%
Navegante	Portugal	Lisbon	010011	50	79%
Moovit	USA	San Francisco	111101	47	75%
Cowlines	Canada	Vancouver	110101	43	68%
Ualabee	Argentina	Buenos Aires	110101	43	68%
Mobilitatsshop	Germany	Hannover	110001	35	56%
WienMobil	Austria	Wien	110001	35	56%
XXImo (Radiuz)	Netherlands	Utrecht	111110	31	49%
Umo Mobility	USA	San Diego	111110	31	49%
Ubigo	Sweden	Gothenburg	111110	31	49%
Bolt	Estonia	Tallinn	011100	14	22%
Freenow	Portugal	Lisbon	011100	14	22%
LexyPass	Finland	Helsinki	101100	13	21%
Uber	USA	San Francisco	001110	12	19%
City Trips	Spain	Barcelona	110000	3	5%

With this additional step, IMPReSS ranking could solve the problem identified by Bandeira's false equivalence, where two systems present the same score. Within IMPReSS, equal scores mean systems with equal conditions.

Regarding the results, Ubigo scored 49% because it lacks societal goals, whereas Transport for London scored 87%. Both have one feature missing, but the impact on the score is significantly different. This is why IMPReSS is useful, as it does not value what makes a system run, but rather what it is running for. This also makes sense, as in the end, Ubigo was a pilot and ended a few years back, while systems that were awarded a 1 in societal goals are still running to this date, 12 out of the sample of 20 systems. One of the systems that was awarded a 100% was ZUM, a relatively new system created by the start-up Meep, involving both public authorities and private operators, proving that deploying a complete MaaS system is also possible in small cities.

4.6 Discussion

IMPReSS allows practitioners and researchers to characterize, identify, and adequately assess transportation services and their true potential to become a fully integrated MaaS system by identifying improvement opportunities. The proposed classification method also facilitates governance decisions, one of the prominent voids in MaaS literature, and incentivizes companies to climb the "ladder." The simplicity and objectivity of IMPReSS also bring flexibility and ease of communication to the intermediate decision-making processes of private/public enterprises, as well as public participation. In the end, for MaaS to fulfill its potential, it must show value in both sustainability (social and environmental) and profitability to be attractive to public authorities and private investors.

The main contribution of this Chapter is the classification method, which, from a qualitative approach, fills the gaps of current MaaS topologies; however, as we dig deep and analyze each of the dimensions, it is possible to visualize that sublevels need to provide more detail about the system's structure (and perhaps consider the user experience). Nevertheless, this would increase the scheme's complexity, making it more information-greedy, which, to date, given the stage of most MaaS systems, would be impossible to obtain. This is especially true in the societal goals dimension, as the actual impacts of these MaaS-like systems on accessibility, equity (Di Ciommo and Shiftan, 2017), and the environment are yet to be measured or identified.

The binary approach presents an explicit limitation, as it falls short of defining “to what extent?” a dimension is incorporated (in the case of a score of 1). For instance, in the societal goals dimension, some might argue that Uber deserves to be awarded a “1” given its geographic coverage and that it undoubtedly increases accessibility (Li et al., 2022). However, evidence corroborates that such ride-hailing services exacerbate externalities, such as congestion (Tarduno, 2021), and pollution, or exclude certain population segments (Liu et al., 2020; Tirachini, 2020). At the same time, Whim has a “1” in the Societal goals category. However, besides changes in accessibility levels, it is working closely with the municipality and encouraging sustainable modes, which could mean a “solid 1” or higher than one.

The proposed method refrains from over-complicating the assessment in this stage, given that most systems are just initiatives or startups with little information available for a detailed score. Nonetheless, efforts to define detailed sub-levels are already being conducted, enabling a more detailed classification when more information, data, and impact results become available. Regarding the ranking proposal, I acknowledge the need for validation, which we will address in future work by conducting a Delphi study.

The “societal goals” category is the most difficult to classify, as no quantitative studies of MaaS impacts exist. However, there are some efforts (from some companies) to show their intention toward societal goals (CO_2 emissions, health conditions, awareness). Nonetheless, in the end, there are no clear incentives for choosing sustainable modes, which means people still choose their mode and route based on individual (and not collective) utility maximization. This is why the same criteria as Sochor et al. (2018a) were adopted for awarding a 1, as presented in Table 2.

As a complementary step, a scoring method is proposed, aimed at facilitating the comparison of MaaS systems. It is important to note that this method is only a preliminary proposal and has a few limitations. It is presented with the intention of initiating a discussion and encouraging further development. The main limitation lies in the assignment of weights to the various features, which increases exponentially as we move towards the right in the binary number. Assigning a significantly higher weight to the rightmost features may be justifiable given the complexity involved in achieving those levels. However, I recognize the importance of validation from experts and stakeholders, as there is currently no available evidence on how to appropriately weigh each dimension in the classification system in order to generate a final score.

As the scoring system and its results are in a preliminary stage, there are three main limitations. First, the results are based on a non-exhaustive list of systems to be assessed, meaning there is still space for expansion. Second, the binary assessment was adopted to guarantee an easy-to-read topology. However, there is still space for a more detailed evaluation, by adopting sublevels (e.g., instead of 0 and 1, the systems could adopt levels, such as (0) not included, (1) partially included, and (2) included), which can be addressed in future developments based for instance in the topology developed by (Lajas and Macário, 2020). This approach would increase the complexity of the method, making it more information-greedy, which, to date, given the stage of most MaaS systems, such information would be too difficult to obtain. Hence, this method could evolve in line with the development and information availability of MaaS systems. Third, it does not incorporate aspects associated with the user's experience, as it is focused on objectively and directly measurable characteristics of MaaS systems. This qualitative-oriented assessment might be useful when MaaS planning is committed to addressing users' well-being issues and to a more participatory approach, which impacts the equity (Di Ciommo and Shiftan, 2017) and willingness to use the service (Pangbourne et al., 2020b; Tsouros et al., 2021).

4.7 Conclusions

The IMPReSS method proved to be a valuable tool to analyze different systems and identify opportunities for improvement by classifying and assessing both established and emerging MaaS systems and new and traditional mobility trends transitioning towards integrated services. This procedure was based on the previous MaaS classification schemes studies found in the literature and works as a complementary tool for providing a more comprehensive assessment. It is evidenced that some dimensions are more important to reach an equitable MaaS, and that different systems have different degrees of MaaS “completeness,” but that it is not necessarily incremental. Existing topologies fail to identify and correctly assess these systems.

In addition to the theoretical contributions stemming from the conceptual debates surrounding the core components that make up a MaaS, the proposed classification scheme has the potential to assist in clearly distinguishing between complete and “emerging” or “aspiring” MaaS systems (Hensher et al., 2021b), as well as recognizing their benefits. It can also aid decision-makers in evaluating the completeness of existing services, facilitating policymaking and regulation. Also, it proves that there exist transport services that could become a full MaaS with small interventions, and these are frequently disregarded when talking about MaaS, as is the case with Lisbon’s Navegante, which already has the more complex dimensions covered. Finally, it provides researchers with a tool for discussing the benefits of shared mobility services and comprehensively comparing them.

For future developments, the classification method should be extended by including different aspects that define in a more precise manner each feature that go beyond the binary approach if a more specific assessment is needed, e.g., payment and validation options, route criteria definition, specific modes included, etc.; on the other hand, the ranking system should address user satisfaction and willingness to use as criteria for scoring the MaaS system, also considering add-on services such as food delivery or vouchers could be integrated. Validation from stakeholders is also needed to provide adequate weights to the different features.

This chapter finalizes part A of the thesis, where I provided a global overview of MaaS, the current framework, and the author’s approach for MaaS implementation and classification.

PART II

User Acceptance, Preferences, and the Expansion of MaaS Services

What are the needs, preferences, and behaviors of users in relation to MaaS services and bundle configurations?

Sub questions:

1. *Are all latitudes ready for a widespread MaaS adoption? Are commuters willing to use it?*
2. *Is a universal MaaS bundle feasible?*
3. *Should MaaS include more than personal mobility services?*

Chapter 5: Do we really want it? Exploring the MaaS acceptance model in 10 cities

This chapter is under review as a journal article: Mauricio Orozco-Fontalvo, Oscar Oviedo-Trespalacios, Sergio Useche, Sylvia Y. He, Sonia Mangones, Marc Hasselwander, Margareth Gutierrez, Ana Karina Christ, Hannah Hook, Mohammed Abouelela, Lenin Bulla-Cruz, Jorge Bolivar-Redondo, Filipe Moura, (2025) Do we really want it? Exploring the MaaS acceptance model in 10 cities, Transportation Research Part A: Policy and Practice [Manuscript under review]

Summary

This chapter presents the “MaaS Acceptance Model” and the application of the IMPReSS method to classify transport systems and conduct a multi-group analysis. I argue that transport innovations are frequently characterized as ‘disruptive’ in public discourse, yet their acceptance by mobility services’ users varies partly due to underlying social-psychological factors influencing their decisions, with responses varying across different user groups and contexts. This chapter investigates user perceptions and attitudes affecting MaaS adoption, demonstrating that a one-size-fits-all approach is inadequate due to the diverse needs and contextual factors that shape user acceptance. I applied a revealed and stated preferences survey in 10 cities across Europe, Latin America, Africa, and Asia, assessing preferences and attitudes toward MaaS and new mobility services. A structural equation model was then estimated, followed by a multi-group analysis, stratified by the development level of local transport networks. The results show that latent constructs, such as Performance Expectancy and Social Influence, significantly affect the intention to use MaaS, while Commute Satisfaction reduces this intention. Moreover, the impact and significance of latent constructs vary depending on the degree of transport system development. I conclude that the main potential of MaaS lies in cities with lower levels of transport digitalization and integration, where user dissatisfaction provides more room for its acceptance. Conversely, in more developed systems, where transport services are already highly integrated and user satisfaction is higher, the value proposition of MaaS must be more carefully tailored to address specific unmet needs.

5.1 Introduction

The digitalization and electrification of transport services, along with the rise of shared and micro-mobility and automation, have significantly influenced and reshaped urban mobility dynamics over the past few decades (Sperling, 2018). Many of these new mobility services were initially expected to revolutionize the sector. However, their impact has often fallen short of expectations, with slow user adoption emerging as one of the primary challenges (Abouee-Mehrizi et al., 2021; Bezai et al., 2021; Curtale et al., 2021; Samadzad et al., 2023). For instance, the Segway was once predicted to transform mobility in the same way the iPhone revolutionized telecommunications, even being hailed as the "invention of the century". Yet, it ultimately failed due to the lack of social acceptance and insufficient market readiness, underscoring the importance of aligning technological innovation with users' needs and societal context (Clark et al., 2019; Kelly et al., 2023). Conversely, shared e-scooters were rapidly embraced by the public, but this time, cities were unprepared for their success (Orozco-Fontalvo et al., 2022). This lack of readiness resulted in regulatory voids, operational challenges, and safety concerns (Félix et al., 2023), ultimately leading to bans in some cities. Moreover, this gap highlights the need for alignment between public acceptance and governance.

Another approach to transport innovation focuses on how services are provided rather than on the vehicles themselves. This is where the Mobility as a Service (MaaS) concept emerged (Hietanen, 2014). Over the last decade, MaaS has captured the attention of transportation stakeholders and, in some cases, become the central objective of both private companies and public authorities. However, its widespread adoption has been slower than anticipated due to feasibility, governance, and implementation challenges, dampening the initial enthusiasm. While a few initiatives, such as Jelbi (Berlin) and Umaji (Taiwan), did consolidate, the recent bankruptcy filing of the pioneer MaaS provider "Whim" in early 2024 highlights the difficulty of delivering a seamless, integrated transportation service through a single app, with some already stating the disputed "MaaS is dead" phrase (Chapter 3).

Since then, different approaches to save MaaS have arisen, such as Mobility-as-a-Feature (Hensher and Hietanen, 2022), in which mobility services are bundled with non-mobility ones (e.g., insurance); MaaS.

2.0 (public mobility) (Larco et al., 2024), in which the authors go beyond the technology to also consider infrastructure and regulations, and Chapter 3, which puts MaaS as a tool for public management and not as a business, among others. The final call on MaaS success depends strictly on whether it can capture the necessary users and become sufficiently attractive, wherein, as some authors already argue (Al Haddad et al., 2020; Fioreze et al., 2019; Lopez-Carreiro et al., 2020), attitudes and perceptions can become even more important than socio-demographics or cost-related attributes in the adoption of a new mobility service.

However, none of these approaches considers the users' view on MaaS and how it should be tailored to meet their needs, which is concerning as psychosocial factors play a crucial role in users' adoption (Abouelela et al., 2024; Useche et al., 2022). The specific studies that assess how attitudes influence its acceptance have been scarce and geographically limited. For instance Kim and Rasouli (2022), Lopez-Carreiro et al. (2024), Matowicki et al. (2022) and Schikofsky et al. (2020) conducted their analyses in The Netherlands and north- Eastern Europe. Kriswardhana and Esztergár-Kiss (2024) analyzed MaaS potential in Hungary. There are few MaaS acceptance studies outside of Europe, mainly in Asia (Hasselwander and Bigotte, 2022; Toyama, 2022; Zhao et al., 2023), and none in Latin America or Africa, which hinders understanding of its adoption and interest in the rest of the world.

I argue that deeper and wider insights into user behavior and acceptance are needed to craft the next phase of MaaS evolution and that the results obtained in the European studies are unsuitable for other contexts, meaning that the acceptance varies depending on the cities' characteristics, and pose the question: ***Are all latitudes ready for a widespread MaaS adoption? Are commuters willing to use it?***

In this study, I apply the Extended Unified Theory of Acceptance and Use of Technology to test whether latent constructs directly influence the intention to use MaaS and how different city contexts create different insights. For this, 10 cities across Latin America, Europe, Asia, and Africa were surveyed, grouping them by the corresponding MaaS development stage (using the IMPReSS score, Chapter 4) into low, medium, or high, and estimating a Multi-group Structural Equation Model (SEM)to correlate the score with cities and respondents' attributes.

The contributions of this study are threefold. First, to fill a critical research gap by examining user behavior through latent constructs in MaaS acceptance, a foundational step for MaaS widespread adoption. Second, the cross-sectional approach spans multiple cities, with a significant emphasis on the Global South (Dados and Connell, 2012), providing much-needed insights into regions often underrepresented in MaaS research. Third, deliver actionable guidance for policymakers to design MaaS strategies that align with the specific strengths and developmental trajectories of urban transport systems, ultimately enabling more context-sensitive and effective mobility solutions.

This work is structured as follows: Section 4.2 presents the literature review discussing the previous MaaS studies, technology acceptance theory, and the research hypothesis. Section 4.3 describes the analytical methods used, including survey design, cities studied, and modelling framework. Section 4.4 includes the model results. Section 4.5 frames these findings within previous research, offers avenues for policymakers, and details future research considerations. Section 4.6 concludes by summarizing the impact of this research and its contribution to the field.

5.2 Literature review

To understand MaaS adoption, it is essential to explore its background, its development, its benefits, and its challenges. This section synthesizes key findings from prior studies to frame the discussion of this research, present the research gap and its contribution, followed by the theoretical background and hypothesis development.

5.2.1 Previous studies on MaaS adoption

MaaS relies on the integration and cooperation of several stakeholders, namely Users, Operators (public and private), Mobility Brokers, Technology providers, and Policymakers. Users could experience lower transport costs, increased accessibility, and more reliable information. Operators could benefit from access to a profitable market, Mobility brokers and Technology Providers could expand their businesses, and policymakers could improve the transport system and resource allocation (Lopes et al., 2023).

However, in practice, MaaS implementation and feasibility have faced numerous challenges. Legal, contracting, interoperability, and data-sharing issues often hinder interactions between stakeholders. These issues ultimately impact users' costs, available alternatives, and trust in the system, failing to meet demand requirements. Moreover, the MaaS implementation and pilots have predominantly taken place in higher-income cities with well-developed transport networks (Lopes et al., 2023), raising questions about its relevance and potential in other realities, such as those in the Global South.

Moreover, the specific constraints, challenges, and opportunities of cities in the Global South remain largely unassessed in applied research, making it valuable to address their cases in further studies. This is the focus of my research, where, by analyzing a significant sample of ten cities, I aim to contribute to identifying gaps in current designs and tailoring MaaS solutions to diverse needs.

One of these topics that remains to be addressed and developed further is the role of attitudinal factors (e.g., intrinsic motivations, values, and identity-related issues) that may differentially drive individuals in regions such as the Global South and Global North to adopt (or not adopt) MaaS. Beyond warranting further exploration, these differences may help to elucidate how attitudes toward urban dynamics (including MaaS) are not formed in isolation but are shaped by the interaction of collective experiences and socio-cultural influences (Schikofsky et al., 2020; Zhang et al., 2021).

Another subsequent contribution of this study (which could be indeed pioneering) is that it may provide new insights on how to make "MaaS for the masses", given that it seeks to provide new insights into these underexplored differences, and positioning it as an strategic tool to steer urban mobility, including those where its adoption could drive meaningful chance (Hasselwander and Bigotte, 2023).

5.2.2 Theoretical background and hypothesis development

Acceptance of new technologies has been a strong research topic in the last decades (Kelly et al., 2023), where the unified theory of acceptance and use of technology (UTAUT) is often referred to as explaining technology acceptance and use. Venkatesh (2003) originally designed the UTAUT for organizational and workplace contexts but later expanded it to include the consumer context. The UTAUT2 (Venkatesh, 2012) has since been applied in different fields, including transport (Kopplin et al., 2021; Korkmaz et al., 2021; Nguyen-Phuoc et al., 2024; Nordhoff et al., 2020). In this theory, the author propose several latent constructs that define the behavioral intention to accept and use new technologies, this constructs are Performance Expectancy: The degree to which using a technology will provide benefits to consumers in performing certain activities; Effort Expectancy: The degree of ease associated with consumers'; Social Influence: The extent to which consumers perceive that important others believe they should use a particular technology; Facilitating Conditions: refer to consumers perceptions of the resources and support available to perform behavior; Hedonic Motivation: Fun or pleasure derived from using a technology; Price Value: refer to the benefits perceived compared to the monetary cost of the technology; and Habit: extent to which people tend to perform behaviors automatically because of learning.

MaaS is also a technological innovation (integrating all the services within an app), thus making it suitable to be assessed using this theory. However, some theoretical constructs, such as price value and habit, are not directly applicable to MaaS, given that it is still a new offering, and that, even in MaaS-like systems, users often do not acknowledge they are using MaaS. Moreover, Schikofsky et al. (2020) state that potential users of disruptive innovations are not necessarily aware of costs and net values among different and sometimes complex mobility alternatives. Another construct that can be waived in MaaS acceptance is Facilitating Conditions because its effect is already captured by the Effort Expectancy (Venkatesh et al., 2003). In previous studies, other latent constructs have been assessed to measure MaaS intention to use and ended up being significant, such as sustainability concerns (Kriswardhana and Esztergár-Kiss, 2024; Matowicki et al., 2022) and technological savviness (Kim and Rasouli, 2022; Kriswardhana and Esztergár-Kiss, 2024). Regarding the observed variables that may influence MaaS acceptance, research indicates that car owners are less likely to use the service as the initial goal of reducing car ownership was not achieved in most pilot studies (Hensher et al., 2021b). On the other hand, people who are experienced with mobility apps (e.g., trip planners) and shared mobility services may increase their acceptance. The one-fits-all MaaS solution has already been contested (Lopes et al., 2023; Pickford and Chung, 2019).

However, to the best of my knowledge, no previous studies have quantitatively compared different city contexts and transportation systems in this regard. Thus, to enable such a comparison, it is first necessary to classify and group these contexts. As an alternative, Chapter 4 proposes a comprehensive method to classify MaaS and MaaS-like systems, building on top of the proposal by Sochor et al. (2018a) and addressing its caveats. This method provides direct insights and facilitates the comparison of the 'completeness' of MaaS systems—whether managed by a company or a city—towards achieving a fully integrated MaaS. The binary score is then converted to a decimal value for classification purposes. Based on the final score, systems are categorized as High (>40), Medium (20–40), or Low (<20), with the maximum possible score being 63. I hypothesize that the higher the IMPReSS score, the higher the MaaS acceptance. Figure 7 presents the hypothesized model. Age and gender were used as control variables.

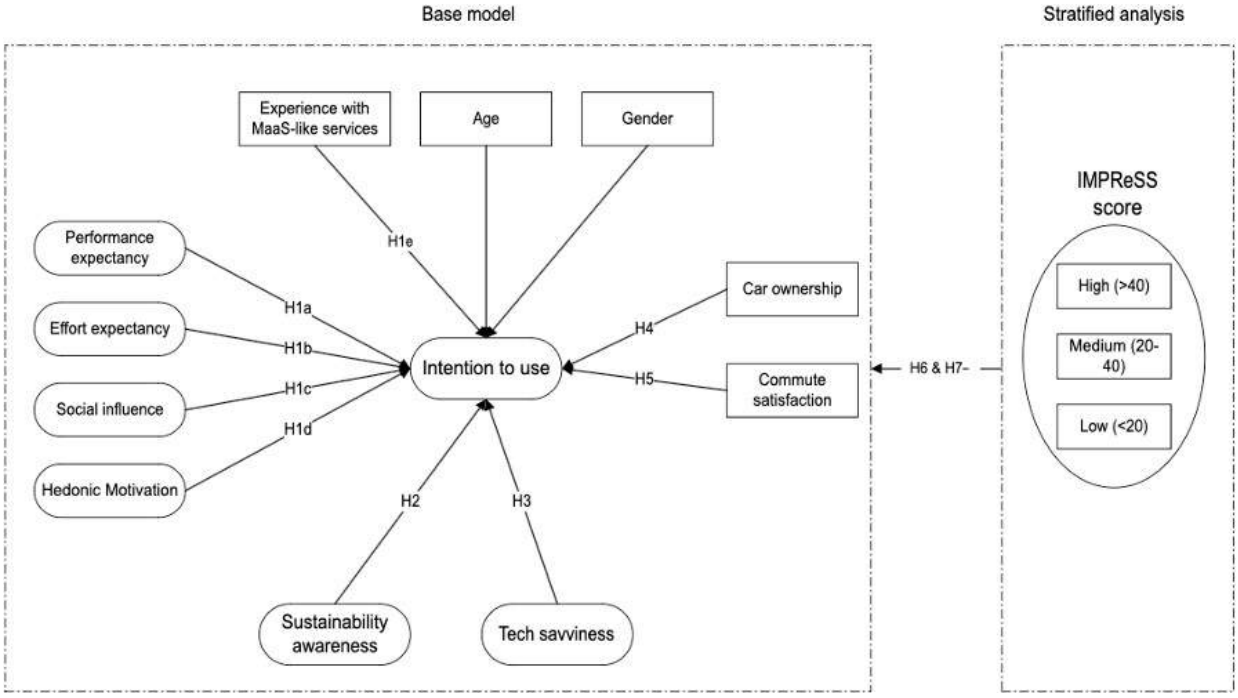
Based on the framework above, the hypotheses tested are as follows:

H1: The defined constructs in the UTAT2 are applicable, and positively and significantly affect the intention to use MaaS.
H1a: Performance expectancy has a positive and significant effect on the intention to use MaaS.
H1b: Effort expectancy positively and significantly affects the intention to use MaaS.
H1c: Social influence positively and significantly affects the intention to use MaaS. H1d: Hedonic Motivation positively and significantly affects the intention to use MaaS.
H1e: Previous experience with mobility apps and new mobility services increases the intention to use MaaS.
H2: Sustainability Awareness directly, positively, and significantly affects the intention to use MaaS.
H3: Tech Savviness directly, positively, and significantly affects the intention to use MaaS.
H4: Car owners are less likely to use MaaS
H5: Users who are more satisfied with their commute are less likely to use MaaS.

H6: The more developed a city's transport system is, the closer it is to a full MaaS (IMPReSS), the higher the intention to use MaaS.

H7: The intention to use MaaS varies based on the city's transport system.

Figure 7. Hypothesis diagram



5.3 Methods

A cross-sectional study of commuters' perceptions and preferences regarding MaaS was conducted. A survey was designed using the LimeSurvey platform (suitable for different devices, including smartphones and tablets) and applied in 10 cities (See Figure 8) with different transport networks, cultural contexts, and socio-demographic conditions. The data were collected between September 2023 and June 2024, and the distribution was done through social media first and then through face-to-face interviews in public spaces, focusing on the underrepresented segments.

5.3.1 Survey design and data collection

The complete survey is part of a project with a wider scope (See Outline: MaaS global survey). This Chapter focuses on the five sections related to MaaS acceptance. In the first section, respondents were asked about their familiarity with the MaaS concept and then presented a brief explanation with an (optional) video for clarification. The second section inquired about travel patterns, including modes and frequency of use, commute time, use of trip planners, and riding skills. The third was related to vehicle ownership, followed by the main section, which used 5-point Likert-scale questions related to the latent constructs adapted from the UTAUT2 to measure the intention to use MaaS. Lastly, respondents reported their socio-demographics, including. It took 15 to 25 minutes to complete, and obtained 3828 valid responses. Table 11 details the statements respondents had to evaluate with the Likert scale.

These indicators were hypothetically explained by latent variables as follows: Performance Expectancy (Perf), Effort expectance (Effort), Social Influence (SocInf), Hedonic Motivation (Hed), and the behavioral intention to use following the UTUAT2 (Venkatesh et al., 2012) and extending it with two proposed constructs based in the literature which are Sustainability Awareness (SusAwr) (Kriswardhana and Esztergár-Kiss, 2023b; Matowicki et al., 2022) and Technological Savviness (TechSav) which encompasses the ability to judge and trust new technologies (Kim and Rasouli, 2022; Kriswardhana and Esztergár-Kiss, 2024) and is built from previous theories as the such as the Technology Acceptance model and previous constructs such as “perceived risk” and “trust”, and respondents ranked them in a 5-point Likert scale ranging from “strongly disagree” to “strongly agree”. The experience with MaaS-like systems was an observed variable that used the frequency of shared modes usage and the use of digital mobility platforms and trip planners as a proxy. Commute satisfaction was also measured on a 5-point Likert scale, where one was “very unsatisfied” and five was “very satisfied”.

Figure 8. Cities covered by the study

To ensure clarity and cultural relevance, the survey was translated into the native language of each city and adapted to local jargon and expressions. In total, the survey was translated from English into five other languages (Portuguese, Spanish, Chinese, Arabic, Dutch), resulting in ten distinct versions (one per city). Each version was specifically customized to the local culture, terminology, and transportation conditions, with variations even within the same country, such as in Colombia, where regional differences in language and context required additional adjustments. To validate its relevance, the versions were developed in collaboration with a local representative from each city. The questionnaire items were equal for each city (except for income level, currency, and prices, which were adjusted for each city). The names of shared mobility services (e.g. Uber, BlaBlaCar, Grab, etc.) were altered to be consistent with each city's operations and services availability. The data collection process varied significantly across cities, requiring tailored incentives and methodologies based on local contexts. In Barranquilla, Manila, Santiago, Ghent, Cairo, and Porto Alegre, a convenience sampling approach using 'snowballing' was employed.

In contrast, trained pollsters conducted surveys in Valencia and Bogota, while specialized data collection companies were hired in Hong Kong and Lisbon. As anticipated, the latter approaches yielded better results overall. However, a notable exception was Manila, where the snowballing method proved unexpectedly effective. To further motivate participation, a raffle offering ten gift cards from an online retailer was used as an incentive. The final sample characteristics are presented in Table 12 & Table 13.

Table 11. Statements presented

No.	Code	Statement
1	Perf_1	MaaS would reduce my commuting time
2	Perf_2	MaaS would improve my commute experience
3	Perf_3	MaaS would be useful for my commute
4	Perf_4	MaaS would help me choose the best alternative for my daily trips
5	Eff_2	New mobility services have clear and understandable instructions
6	Eff_3	New mobility services are easy to learn to use
7	Eff_4	New mobility services are easy to use
8	Hed_1	New mobility services are fun
9	Hed_2	New mobility services are exciting
10	Hed_3	New mobility services are enjoyable
11	SusAwr_2	I believe that integrated mobility services help to fight climate change
12	SusAwr_3	I try to avoid using motorized modes for environmental reasons
13	SusAwr_4	I usually use sustainable modes even if they are more expensive

No.	Code	Statement
14	SusAwr_5	I usually use sustainable modes even if they require more effort
15	SocInf_2	New mobility services are presented as positive or impactful in social media
16	SocInf_3	New mobility services are recommended to me by people whose opinion I value
17	SocInf_4	New mobility services are being used by people who are important to me
18	SocInf_5	My peers are increasingly using new mobility services
19	TechSav_1	I'm capable of using mobility apps
20	TechSav_2	New mobility services are reasonably priced
21	TechSav_3	services like Airbnb, Blabla Car and Uber are better than the traditional alternatives
22	TechSav_5	my personal information is handled appropriately when using mobility apps
23	TechSav_6	the new service providers will deliver reliable and safe transportation options
24	TechSav_7	my payment information will be secure when using Mobility apps
25	IntUse_intend	I intend to use MaaS in the future
26	IntUse_plan	I plan to use MaaS regularly
27	IntUse_use	I will use MaaS daily

Table 12. Sample (population) Characteristics by City

City	Gender			Occupation							Income			Sample (Frequency)
	Man	Woman	Other	Selfemp	Emp	FL	GradS	Retired	UndS	Unemp	High	Medium	Low	
Barranquilla	48% (48%)	51% (52%)	1%	1%	54%	11%	3%	2%	27%	3% (10%)	4%	37%	59%	317
Bogota	51% (47%)	49% (53%)	1%	2%	50%	10%	1%	4%	29%	4% (9%)	24%	45%	31%	497
Cairo	83% (51%)	15% (49%)	1%	1%	19%	1%	6%	1%	69%	8% (10%)	8%	28%	63%	166
Ghent	45% (50%)	46% (50%)	9%	2%	72%	6%	10%	1%	7%	2% (4%)	15%	49%	36%	195
Hong Kong	43% (45%)	49% (55%)	8%	1%	74%	7%	5%	1%	10%	2% (4%)	23%	60%	17%	400
Lisbon	42% (47%)	57% (53%)	2%	4%	61%	5%	2%	2%	24%	1% (7%)	13%	61%	27%	865
Manila	52% (50%)	32% (50%)	16%	3%	60%	9%	6%	0%	18%	4% (5%)	21%	59%	20%	490
Porto Alegre	51% (47%)	47% (53%)	3%	5%	40%	8%	18%	3%	25%	1% (8%)	35%	38%	26%	317
Santiago	54% (51%)	42% (49%)	4%	3%	58%	10%	4%	1%	21%	3% (9%)	29%	35%	36%	281
Valencia	30% (48%)	66% (53%)	4%	2%	30%	3%	6%	2%	54%	4% (11%)	17%	54%	29%	300
Global	**47%**	**48%**	**5%**	**3%**	**55%**	**7%**	**5%**	**2%**	**25%**	**3%**	**19%**	**50%**	**31%**	**3828**

Table 13. Sample (Population) characteristics cont.

City	Age				Education								Sample (Frequency)
	<24	24-34	44-64	>65	Elementary	High-School	Technician	Associate	Bachelors	Masters	PhD	None	
Barranquilla	23% (16%)	38% (22%)	37% (48%)	2% (14%)	2% (12%)	25% (50%)	26%	-	37%	9%	1%	3%	317
								(37%)		(<1%)		(1%)	
Bogota	39% (15%)	32% (26%)	28% (51%)	1% (14%)	0% (32%)	30% (42%)	16%	-	43%	9%	19%	4%	497
								(19%)		(3%)		(5%)	
Cairo	63% (26%)	19% (23%)	17% (39%)	1% (11%)	0% (28%)	26% (28%)	3%	-	51%	10%	4%	8%	166
								(18%)		(n.a.)		(15%)	
Ghent	15% (10%)	47% (24%)	37% (47%)	1% (20%)	1% (9%)	12% (50%)	6%	-	38%	36%	6%	2%	195
								(28%)		(14%)		(1%)	
Hong Kong	15% (7%)	40% (14%)	45% (56%)	1% (27%)	22% (24%)	38% (54%)	0%	13%	15%	10%	1%	2%	400

								(19%)		(3%)		(1%)	
Lisbon	29% (8%)	23% (16%)	45% (48%)	2% (29%)	2% (15%)	34% (30%)	9%	-	34%	18%	3%	1%	865
								(37%)		(n.a.)		(n.a.)	
Manila	15%	58%	2%	0% (5%)	0% (19%)	14% (40%)	12%	-	53%	17%	3%	4%	490
								(35%)		(<1%)		(1%)	
Porto Alegre	25% (12%)	48% (20%)	25% (57%)	1% (11%)	0% (10%)	21% (n.a.)	4%	-	40%	23%	12%	1%	317
								(35%)		(n.a.)		(2%)	
Santiago	16%	40%	42%	1% (14%)	1% (18%)	17% (41%)	15%	-	48%	15%	5%	3%	281
								(36%)		(5%)		(1%)	
Valencia	64% (9%)	9% (15%)	25% (50%)	2% (25%)	1% (17%)	19% (51%)	27%	-	45%	5%	3%	4%	300
								(29%)		(8%)		(1%)	
Global	**47%**	**48%**	**5%**		**4%**	**26%**	**12%**	**-**	**39%**	**15%**	**3%**	**1%**	**3828**

Table 14. Main characteristics of the cities involved

City	Pop.[1] (mill)	Area[1] (Km2)	Pop. density[1](Km2)	GDP per capita[2]	GINI[2]	IMPReSS
Barranquilla	1.30	154	8618	€6600	0.460	Low
Bogota	8.00	1587	20691	€10526	0.530	Medium
Cairo	22.00	3085	19376	€3951	0.315	Low
Ghent	0.26	156	1709	€47300	0.249	High
Hong Kong	7.50	1106	7062	€45064	0.540	High
Lisbon	0.55	100	942/km2	€30500	0.340	High
Manila	1.80	42	43079	€10100	0.420	Low
Porto Alegre	1.50	496	2837	€17628	0.490	Medium
Santiago	7.00	641	8464	€17800	0.440	Medium
Valencia	0.80	135	5998	€24473	0.350	Medium

Note: 1: Source: Thomas Brinkhoff: City Population, http://www.citypopulation.de; 2: Source: https://www.statista.com/markets/2535/topic/970/economT/overview

5.3.2 Cities' characteristics and classification

To conduct the stratified analysis, each city's transportation system was classified using the IMPReSS method. This method allowed us to capture the context of the transportation network, as it accounts for modes availability, digitalization, integration, and societal insights. These cities were selected because they provide a representative sample of the transportation conditions worldwide, an overview of the understudied Global South, and they represent a diverse sample of IMPReSS scoring, with three low, three medium, and four high, allowing us to test the hypothesis among these groups and allowing for comparison with cities with similar characteristics or scores. The cities' main characteristics are presented in Table 14, and the transportation context is presented in Table 15.

5.3.3 Modeling framework

For modeling the relationships between the hypothesized variables and the intention to use MaaS, a Structural Equation Model (SEM) was estimated using the Lavaan package in R (Rosseel, 2012). First, estimate a base model using the complete dataset to test the hypothesis. Then, conducting a multi-group SEM to assess if the structure of the model is equivalent across the different IMPReSS levels, meaning both the variables and the loadings are consistent across multiple groups, called an invariance test (Marôco, 2010).

Table 15. Available mobility statistics of the covered cities[2]

City	PT options	Modal split
Barranquilla	BRT, Bus, Taxi	Car=6%, PT= 57% Walk= 30%, bike= 1%, Mot= 4%, Other=2%
Bogota	BRT, Bus, Taxi	Car=14%, PT= 48%, Walk= 25%, bike= 7%, Mot= 6%
Cairo	Bus, Taxi, Metro, Tram, Train	Car=24%, PT= 61% Walk= 12%, bike= 1%, Mot= 2%
Ghent	Tram, Bus, Taxi, Train	Car=38%, PT= 15% Walk= 13%, bike= 33%, Mot= 2%

[2] PT= Public transport, BS= Bike-sharing, CS= Car-Sharing, ES= E-scooter sharing, MS= Motorcycle-sharing, RH= Ride-hailing, Mot= Motorcycle, Para=Paratransit

City	PT options	Modal split
Hong Kong	Metro, Tram, Bus, Taxi, Ferry	Car=14%, PT= 71% Walk= 12%, bike= 1%, Mot= 1%, Other= 1%
Lisbon	Bus, Train, Metro, Tram, Ferry, Taxi	Car=58%, PT= 16% Walk= 23%, bike= 1%, Mot= 2%
Manila	Train, Bus	Car=8%, PT= 32% Walk= 31%, bike= 2%, Mot= 8%, Para= 18%, Other= 1%
Porto Alegre	Bus, Taxi	Car=29%, PT= 45% Walk= 9%, bike= 6%, Mot= 2%, RH= 7%, Other=2%
Santiago	BRT, Metro, Bus, Taxi	Car=34%, PT= 36% Walk= 46%, bike= 4%, Mot= 2%
Valencia	Bus, Metro, Tram, Taxi	Car=41%, PT= 14% Walk= 41%, bike= 3%, Other= 1%

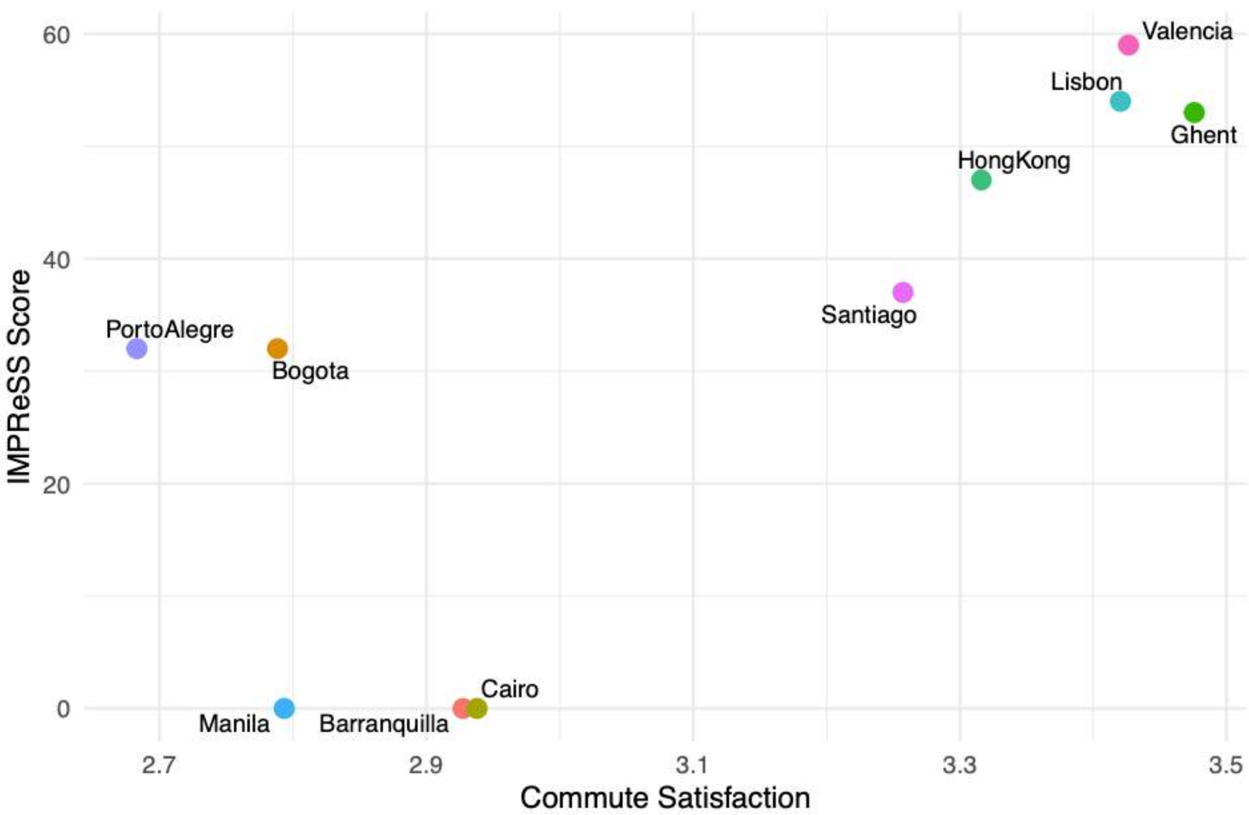
This adds explanatory strength by confirming that the differences between groups are not due to measurement discrepancies but to genuine variations in relationships, hence allowing for a valid comparison of the influence of variables on the intention to use MaaS. The groups for the stratified analysis were the IMPReSS classification of the cities.

The model was estimated using the maximum likelihood method with bootstrapping and 2000 replications. Bootstrapping was employed to account for the lack of multivariate normality in the data, which was expected. It provides a more robust estimation of standard errors by generating numerous random resamples from the original dataset, allowing a distribution of parameter estimates and supporting hypothesis testing even with non-normally distributed data. This technique was suitable for the dataset, given the size and representativeness of the target population. However, it generates wider confidence intervals that could affect the precision of the estimates.

To conduct the invariance test, a set of models was estimated (Van De Scoot et al., 2012):

1. Configural invariance: a model where all parameters are allowed to vary across groups.
2. Metric Invariance: a model where the factor loadings are constrained to be equal across groups, but the intercepts are allowed to vary. This tests whether respondents across groups attributed the same meaning to the latent construct.
3. Scalar invariance: a model where both factor loadings and intercepts were constrained to be equal. This tests whether groups can be compared on their scores on the latent variable.
4. Uniqueness invariance: a model where the residual invariances are also fixed. This tests whether the latent construct is measured identically across groups.

Figure 9. Commute satisfaction avg vs IMPReSS score



5.4 Results

The results are presented in two sections: the base model and the multi-group SEM. The base model presents the results for the complete dataset, and the multi-group SEM presents the results for the stratified analysis of IMPReSS classification groups. The comparison between Commute Satisfaction and IMPReSS scores highlights this contrast: in cities with higher IMPReSS scores, more than half of respondents expressed high satisfaction with their commutes, whereas in cities with lower scores, less than a third of respondents reported the same. This is presented in Figure 9.

Regarding the validity of the constructs, Table 16 shows the reliability coefficients (Cronbach's alpha and Omega) and the Average Variance Extracted (AVE) for each construct. I present both the Cronbach's alpha as it is commonly used, and the McDonald's omega as it is considered more reliable, especially for congeneric items (when essential tau-equivalence is violated), as it accounts for the dimensional structure of the data (Hayes and Coutts, 2020). Congeneric items refer to indicators that are assumed to measure the same underlying construct, but they may vary in their loadings or variances, as is the case in this example.

The reliability coefficients are above the threshold of 0.8, except for Hedonic Motivation, which is close to 0.7 and can be considered acceptable. The values for Omega and Omega2 are equal, which indicates that there are no "dual-loadings" of the indicators, as Omega2 is also known as unconditional reliability (Flora, 2020). Finally, AVE further supports construct validity by assessing the proportion of variance captured by the construct relative to the total variance, with all constructs showing adequate convergent validity.

Table 16. Reliability and Validity Measures for Constructs

	Perf	SusAwr	Effort	Hedonic	Socinf	TechSav	IntUse
Alpha	0.879	0.835	0.821	0.672	0.808	0.776	0.838
Omega	0.880	0.838	0.830	0.680	0.811	0.782	0.841
Omega2	0.880	0.838	0.830	0.680	0.811	0.782	0.841
Omega3	0.880	0.839	0.833	0.685	0.812	0.787	0.842
AVE	0.647	0.634	0.556	0.416	0.588	0.422	0.639

5.4.1 Base model

The base model diagram is presented in Table 17. The latent variables had factor loadings above 0.3, and a cumulative variance of 0.62, which is considered acceptable and valid for this type of model (Marôco, 2010). We obtained a good fit with a CFI of 0.95, a TLI of 0.94, and an RMSEA of 0.042. Regarding the regressions, as expected, Performance Expectancy proved to be one of the stronger predictors of the behavioral intention to use MaaS (Estimate= 0.314, p< 0.001) supporting H1a.

Early Working Age adults have a higher enjoyment derived from using the service, Hedonic Motivation, (Estimate = 0.046, p = 0.003), while Middle Age respondents find it difficult to use new mobility services (Estimate = -0.102, p=0.047). This suggests that age plays a role in the perception of MaaS, where younger users may find the service more intuitive and enjoyable, while older users encounter barriers to adoption. Previous studies have shown that ride-hailing services are mostly used by young, educated people (Nguyen-Phuoc et al., 2021). Interestingly, gender does not have a significant impact on the intention to use MaaS, as seen from the non-significant coefficient (Estimate = -0.023, p = 0.31). This implies that gender differences are not a key factor in shaping user perceptions or intentions regarding MaaS adoption, which can be an opportunity to reduce the gender gap in transport, as women have different travel patterns and often conduct segmented trips, which can be better served by MaaS (Balarezo et al., 2024; McIlroy, 2023). On the other hand, car owners are less likely to use MaaS (Estimate = -0.042, p = 0.06), which is in line with the literature as several studies evidence the difficulty of shifting from private car to MaaS (Alonso-González et al., 2020; Fioreze et al., 2019; Hensher et al., 2021a; Storme et al., 2020), thus supporting H4.

Other demographic and attitudinal factors also play critical roles in MaaS adoption. Technological Savviness is a strong predictor of both the Performance Expectancy (Estimate = 1.087, p < 0.001) and Social Influence (Estimate = 0.850, p < 0.001), indicating that those more comfortable with technology are more likely to find MaaS convenient and be influenced by others to adopt it. Previous experience with MaaS significantly enhances Effort Expectancy (Estimate = 0.284, p < 0.001) and also increases the likelihood of adoption (Estimate = 0.201, p < 0.001), suggesting that familiarity with the service is a major driver of intention.

Table 17. SEM results

Predictor		Outcome	Estimate	Std.Err	Z value	P value
Earlyworksage	→	IntUse	0.106	0.022	4.720	0.000
CommuteStsfctn	→	IntUse	-0.036	0.011	-3.196	0.001
Gendhom	→	IntUse	-0.023	0.022	-1.023	0.306
ExperienceMaaS	→	IntUse	0.201	0.035	5.675	0.000
Carown	→	IntUse	-0.042	0.022	-1.883	0.060
Perf	→	IntUse	0.314	0.018	17.026	0.000
SusAwr	→	IntUse	0.066	0.014	4.728	0.000

Predictor		Outcome	Estimate	Std.Err	Z value	P value
Hedonic	→	IntUse	0.047	0.038	1.257	0.209
Socinf	→	IntUse	0.133	0.024	5.554	0.000
Eff	→	IntUse	-0.008	0.020	-0.403	0.687
TechSav	→	Perf	1.087	0.066	16.433	0.000
Middleage	→	Eff	-0.102	0.051	-1.987	0.047
Earlyworksage	→	Hedonic	0.046	0.021	2.151	0.031
ExperienceMaaS	→	TechSav	0.128	0.032	4.023	0.000
ExperienceMaaS	→	Eff	0.284	0.050	5.676	0.000
TechSav	→	Socinf	0.850	0.040	21.351	0.000
TechSav	→	SusAwr	0.368	0.046	7.996	0.000
TechSav	→	Socinf	0.272	0.033	8.143	0.000

Additionally, Sustainability Awareness (Estimate = 0.066, $p < 0.001$) and Social Influence (Estimate = 0.133, $p < 0.001$) have a positive impact on the intention to use MaaS, highlighting the importance of environmental consciousness and social networks in shaping user behavior. Together, these findings highlight the need for MaaS strategies that consider both technological familiarity and attitudinal factors, such as Social Influence and environmental benefits, to encourage broader adoption across diverse demographic groups. This confirms H1c, H1e, H2 and H3.

On the other hand, (and supporting H5) Commute Satisfaction had a negative effect, indicating that respondents who are more satisfied with their current commute are less likely to use MaaS. This is an interesting result, and it can be explained by the fact that people who are satisfied with their situation are less likely to modify it by trying new services.

Surprisingly, Effort Expectancy was not significant, which could be explained by the fact that respondents are already familiar with similar technologies and do not see it as a barrier to using MaaS, which leads to the rejection of H1b. The Hedonic Motivation was also not significant (rejecting H1d), though this latent variable was found to be significant in previous studies regarding e-scooters (Kopplin et al., 2021; Orozco-Fontalvo et al., 2024a). This indicates that respondents view MaaS primarily as a utilitarian service rather than something fun or exciting, as was the case in those studies. However, Schikofsky et al. (2020) concluded that Hedonic Motivation had a similar impact as perceived usefulness behavioral intention. Such results could be related to the collected sample dates, i.e., in 2017, shared mobility and mobility apps were still quite a novelty, potentially increasing the Hedonic Motivation construct. The data collection was conducted in 2024 when these mobility services and corresponding apps were widespread, and most citizens were aware of them, as the Effort Expectancy result confirms. These results indicate that not all the constructs defined in the UTAUT2 apply to the intention to use MaaS. This is opposite to the results by Kriswardhana and Esztergár-Kiss (2024), where Effort Expectancy was significant for two of the three clusters tested.

5.4.2Multi-group Structural Equation Model (SEM)

A single base model cannot adequately capture the differences in MaaS acceptance among city groups with varying developmental stages (H7). The configural model (Table 18) demonstrated a satisfactory fit to the data (χ^2= 3905.1, df = 1197, $p < 0.001$), suggesting that the model's basic structure was consistent across groups. However, subsequent testing for metric (weak) and scalar (strong) invariance revealed significant differences. When constraining the factor loadings to be equal across groups (metric invariance), the chi-square difference test was highly significant ($\Delta\chi^2$ = 213.59, df = 36, $p < 2.2e\text{-}16$), indicating that the relationships between the observed variables and their underlying latent constructs differ significantly across the levels of MaaS development. This result suggests that the way respondents in different groups perceive and interpret the constructs, such as Performance Expectancy, Sustainability Awareness, and Effort Expectancy, is not uniform.

Further testing for scalar invariance, which involved constraining the factor loadings and intercepts to be equal across groups, also resulted in a significant chi-square difference ($\Delta\chi^2 = 566.17$, df = 36, $p < 2.2e\text{-}16$). This finding implies that not only do the relationships between the latent constructs and their indicators differ, but the baseline levels of these indicators also vary across groups. Therefore, the assumption of equal measurement across different levels of MaaS development is not supported.

Table 18. Multigroup SEM (MGSEM) Results

Predictor		Outcome	Estimate			Standard Error			Z value			p-value		
			High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
Earlyworksage	→	IntUse	0.16	0.026	0.06	0.044	0.042	0.032	3.535	0.604	1.862	0.000	0.546	0.063
CommuteStsfctn	→	IntUse	-0.01	-0.025	-0.03	0.020	0.021	0.017	-0.287	-1.209	-1.698	0.774	0.227	0.090
Gendhom	→	IntUse	-0.04	-0.097	-0.001	0.038	0.040	0.033	-0.962	-2.405	-0.046	0.336	0.016	0.963
ExperienceMaaS	→	IntUse	0.19	0.077	0.17	0.047	0.066	0.069	3.944	1.160	2.468	0.000	0.246	0.014
Carown	→	IntUse	-0.02	-0.028	-0.02	0.044	0.040	0.035	-0.429	-0.707	-0.513	0.668	0.480	0.608
Perf	→	IntUse	0.30	0.403	0.19	0.028	0.037	0.034	10.860	10.814	5.631	0.000	0.000	0.000
SusAwr	→	IntUse	0.07	0.068	0.001	0.020	0.022	0.041	3.288	3.060	0.032	0.001	0.002	0.975
Hedonic	→	IntUse	0.13	-0.095	0.03	0.053	0.067	0.082	2.370	-1.411	0.391	0.018	0.158	0.696

Predictor		Outcome	Estimate			Standard Error			Z value			p-value		
			High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
Socinf	→	IntUse	0.07	0.119	0.28	0.036	0.030	0.065	1.945	3.964	4.311	0.052	0.000	0.000
Eff	→	IntUse	0.01	-0.022	0.03	0.030	0.033	0.052	0.236	-0.671	0.474	0.813	0.502	0.635
TechSav	→	IntUse	0.15	0.298	0.18	0.074	0.066	0.094	2.057	4.548	1.911	0.040	0.000	0.056
TechSav	→	Perf	1.40	0.903	1.04	0.191	0.139	0.067	7.361	6.510	15.506	0.000	0.000	0.000
Middleage	→	Eff	-0.21	-0.028	0.10	0.071	0.106	0.105	-2.988	-0.264	0.896	0.003	0.792	0.370
ExperienceMaaS	→	Eff	0.24	0.332	0.22	0.064	0.112	0.101	3.697	2.966	2.202	0.000	0.003	0.028
Earlyworksage	→	Hedonic	-0.02	-0.009	0.07	0.041	0.037	0.031	-0.577	-0.231	2.200	0.564	0.817	0.028
ExperienceMaaS	→	Hedonic	0.09	0.039	0.14	0.041	0.070	0.063	2.198	0.560	2.281	0.028	0.576	0.023
Eff	→	Hedonic	0.23	0.300	0.50	0.027	0.032	0.029	8.452	9.471	16.995	0.000	0.000	0.000
ExperienceMaaS	→	TechSav	0.08	0.148	0.11	0.033	0.059	0.066	2.458	2.504	1.698	0.014	0.012	0.089

Predictor		Outcome	Estimate			Standard Error			Z value			p-value		
			High	Medium	Low	High	Medium	Low	High	Medium	Low	High	Medium	Low
Eff	→	TechSav	0.26	0.320	0.69	0.032	0.043	0.043	8.116	7.505	16.117	0.000	0.000	0.000
TechSav	→	Socinf	0.94	0.804	0.88	0.084	0.091	0.051	11.252	8.815	16.342	0.000	0.000	0.000
TechSav	→	SusAwr	0.22	0.209	0.52	0.102	0.093	0.081	2.181	2.234	6.391	0.029	0.025	0.000
Socinf	→	SusAwr	0.23	0.305	0.19	0.055	0.052	0.079	4.170	5.834	2.460	0.000	0.000	0.014

These findings support the hypothesis that a one-size-fits-all model is not suitable for assessing MaaS acceptance across different cities (H7). The lack of metric and scalar invariance indicates that the relative importance and meaning of MaaS-related constructs differ across urban contexts. This suggests that respondents in cities at different stages of MaaS maturity interpret and prioritize latent constructs in distinct ways. Consequently, MaaS design and policy strategies should be adapted to local sociocultural and infrastructural conditions rather than assuming universal behavioral patterns.

Moreover, the latent constructs and other predictors vary across groups. For instance, as expected, Commute Satisfaction was not significant in the High and Medium IMPReSS groups, which aligns with the argument in the base model as this variable is not relevant to define MaaS usage in these groups. Hedonic Motivation is significant in the High IMPReSS group but not in the Medium and Low. Sustainability Awareness is significant in both the High and Medium IMPReSS groups but not in the Low one. These results were expected as users would prioritize other features before sustainability or enjoyment in a poor transportation setting.

Other notable differences between constructs are that Performance Expectancy is consistently a strong predictor across all groups, while it appears particularly influential in the High IMPReSS group. Social Influence seems more relevant in the Low group more than the others, implying that social factors are crucial for this segment. Tech Savviness substantially positively effects all groups, particularly in influencing Performance Expectancy. In short, the High IMPReSS group prioritizes Performance Expectancy and Technological Savviness as critical drivers for adopting MaaS, reflecting a more pragmatic and tech-savvy outlook. However, users in these cities are the least interested in the service. The Low IMPReSS group, while still valuing Performance Expectancy, is more impacted by Social Influence, perhaps due to less familiarity with the technology. The Medium IMPReSS group balances these trends, with moderate scores across most latent variables.

5.5 Discussion and Policy Implications

This discussion focuses on the key findings from the multi-group analysis of MaaS acceptance across cities with varying levels of transportation system development. To guide this analysis, the factors that influence the intention to use MaaS are explored, with particular attention to the diverse impacts of socio-demographic characteristics, user satisfaction, and local transportation contexts. By examining how factor loadings such as Performance Expectancy, Sustainability Awareness, and Social Influence differ between cities with high, medium, and low IMPReSS scores, we aim to understand how these differences influence MaaS adoption and to identify the contextual conditions that facilitate or hinder its success. The discussion is structured to provide insights into how these findings relate to broader policy implications for promoting MaaS in different urban environments.

Overall, these findings suggest a strong but negative relationship between the maturity of urban transport systems and the likelihood of MaaS adoption, leading to the rejection of H6. In cities with highly developed and efficient transport networks, where 52% of respondents reported being highly satisfied with their daily travel experiences, there is less incentive to adopt MaaS. The convenience and reliability of the existing infrastructure reduce the perceived benefits of switching to new, integrated mobility solutions.

5.5.1 Is it 'that different' between the Global South and the Global North?

While a categorical answer to this question would require further studies, variables, and broader coverage, the findings from the cities analyzed suggest that key differences may indeed exist. This is reflected in the multi-group analysis, where Commute Satisfaction was not a significant factor for the intention to adopt MaaS in high and medium IMPReSS groups. This insignificance suggests that in such contexts, users do not rely on their Commuting Satisfaction to guide their decision-making about MaaS adoption. Consequently, MaaS faces a bigger challenge in these cities; it cannot rely on merely improving the perceived quality of commuting but must offer additional incentives or unique value propositions to attract users.

In contrast, in cities with lower transport system maturity, where only 28% of commuters report high satisfaction, MaaS becomes a more attractive option. These cities, often in the Global South, such as Bogota, Cairo, and Manila, face significant mobility challenges, including long travel times, unreliable services, and fragmented transport modes (Jahangir et al., 2024). In such contexts, MaaS has the potential to integrate even existing informal transport services, offering a more cohesive and reliable transport solution that addresses unmet user needs.

From a transport justice perspective, this suggests that MaaS can play a relevant role in improving the overall quality of urban transport in cities with mobility poverty, which is deepened by latent issues such as insecurity, inaccessibility, and lack of transport choices (Alfaro et al., 2024; Durand et al., 2022). Based on this study, the IMPReSS linked to the results shows that the fundamental idea behind MaaS -a seamless digital integration of various transportation modes- leads to higher overall Commuter Satisfaction. This indicates that cities prioritizing innovation, integration, multimodality, and digitalization of their transport services tend to have more satisfied users.

The Multi-Group Structural Equation Model (SEM) analysis indicates that latent constructs, such as Performance Expectancy, Tech Savviness, and Social Influence, are key factors influencing the intention to adopt MaaS, particularly in cities with less developed transport systems. These attitudinal factors, in many cases, outweigh traditional considerations like cost and time savings. In other words, this the importance of psychosocial factors in user decision-making processes. Therefore, a successful MaaS strategy must be flexible and tailored to specific urban contexts, recognizing the diversity in user expectations and infrastructure maturity. Ultimately, MaaS adoption will depend on adaptive, user-centered solutions that address both the practical and attitudinal needs of commuters across different cities.

5.5.2 Different social influences… different choices and policy needs?

Building on the aforementioned points, the results highlight the significant impact of Social Influence on the intention to use MaaS –a factor often overlooked in policy discussions-, suggesting that community dynamics and peer endorsements are crucial in driving adoption. In contrast, Effort Expectancy, traditionally emphasized in technology acceptance models, was not significant in the general model, suggesting that users' familiarity with similar digital platforms makes usability less critical. Additionally, the non-significance of Hedonic Motivation implies that MaaS is perceived more as a functional solution than an enjoyable experience, perhaps reflecting its established status in the mobility ecosystem.

In other words, these findings reveal that in the context of MaaS, practical and social benefits are more impactful than usability or enjoyment, suggesting a more complex adoption landscape where attitudes toward Performance Expectancy, Sustainability Awareness, and Social Influence surpass the influence of technology-related factors. Coherently, some of the few existing studies highlight how it is important that, to guarantee access to the service, MaaS systems operators work closely with communities to ensure inclusivity. For instance, elderly individuals who may have low digital literacy may experience significant challenges interacting with these platforms (Durand et al., 2022; Zhang and Yang, 2024), which was not reflected in the results possibly due to the low sample of elderly respondents, which is one of the limitations of this study. Table 19 presents a summary of the hypothesis evaluation.

Based on these insights, a feasible practical implication could be that policymakers should prioritize MaaS implementation in cities with lower transport maturity (in terms of IMPReSS) such as Bogota or Manila, where commuter dissatisfaction and fragmented transport networks offer a strategic opportunity to improve mobility integration and service reliability. In these settings, MaaS can serve as a coordinating platform to unify informal and formal transport services, ultimately enhancing accessibility and commuter satisfaction. For cities with advanced, integrated systems like Hong Kong or Ghent, where commuter satisfaction is already high, MaaS adoption may require a more tailored, value-added approach, such as offering premium features or customizable service options that meet specific user needs.

In this context, the results also suggest that Social Influence invests special importance for reinforcing the need for policy strategies that leverage social networks and community influence to foster awareness and interest in MaaS. For example, collaborating with local influencers or community groups could strengthen a community-driven push toward MaaS adoption, particularly in regions where technological familiarity varies. Furthermore, as previous studies indicate, income is not a significant determinant of MaaS adoption (Hasselwander and Bigotte, 2022), marketing and educational campaigns should focus broadly on increasing awareness of MaaS benefits, rather than targeting specific income groups. By aligning MaaS strategies with the attitudinal drivers of Performance Expectancy, Social Influence, and Sustainability Awareness, and by considering the unique transport needs of each city, policymakers can effectively optimize MaaS adoption potential and contribute to its long-term success.

MaaS, at its core, represents the ongoing evolution of transport systems and integration efforts implemented in cities worldwide, often without the formal “MaaS” label. As results show, in cities with high IMPReSS many individuals have already been using systems that embody the principles of “MaaS” without being aware of it. This suggests that the focus need not to be on defining MaaS but on enhancing the elements that contribute to greater mobility-related satisfaction. Nevertheless, the MaaS label remains valuable for quickly referencing the ideal model for integrating mobility services that cities should aim to offer. It also serves as a standardized term in regulatory and policy documents to avoid legal ambiguities due to interpretation.

Table 19. Hypothesis summary

No.	Hypothesis	Result	Conclusion
1	H1	Not all the constructs in the UTAT2 influence the intention to use MaaS.	Partially endorsed
2	H1a	Performance Expectancy positively and significantly affects the intention to use MaaS.	Endorsed
3	H1b	Effort Expectancy does not affect the intention to use MaaS.	Rejected
4	H1c	Social Influence positively and significantly affects the intention to use MaaS.	Endorsed
5	H1d	Hedonic Motivation does not affect the intention to use MaaS.	Rejected
6	H1e	Previous experience with mobility apps and new mobility services increases the intention to use MaaS.	Endorsed
7	H2	Sustainability Awareness directly, positively and significantly affects the intention to use MaaS.	Endorsed
8	H3	Tech Savviness directly, positively and significantly affects the intention to use MaaS.	Endorsed
9	H4	Car owners are less likely to use MaaS	Endorsed
10	H5	Users who are more satisfied with their commute are less likely to use MaaS.	Endorsed
11	H6	The more developed a city’s transport system is, the higher the intention to use MaaS.	Rejected
12	H7	The intention to use MaaS varies based on the city’s transport system.	Endorsed

5.6 Conclusions

In this work, a MaaS survey was conducted in 10 cities with different transportation contexts and network development to assess the MaaS acceptance based on the UTAUT2. The results show that the intention to use MaaS is influenced by the city's transport system development (according to the IMPReSS method). Still, contrary to H1, the higher the IMPReSS score the less intention there is to use MaaS. On the other hand, H2 is supported as the model indicates that the influence of the latent constructs on the intention to use MaaS varies based on the city's transportation context. This suggests that a one-size-fits-all model is unsuitable for assessing MaaS acceptance across different cities, and that local context and development level should be considered when designing MaaS policies and strategies. Moreover, H3 was partially supported as the defined constructs positively and significantly influence the intention to use MaaS, except for the perceived Effort Expectancy as it seems respondents are already familiar with dealing with this kind of apps.

The main finding is that MaaS acceptance is higher in cities with a low IMPReSS score due to a lower commute satisfaction level. Hence MaaS stakeholders and advocates should focus on cities with similar characteristics instead of (as has been done in the last decade) trying to implement in cities with an already reliable and robust transport system. This is also an opportunity to improve transport equity (on a global scale) for those in low-IMPReSS cities.

The main value of this study is its thorough multi-city comparison, which incorporates a sizable number of cities from the Global South, a region that is frequently under-represented in transportation studies. By examining MaaS adoption across diverse contexts, the findings highlight the need go beyond the notion that solutions implemented in the Global North will universally apply for the rest of the world. The findings emphasize how crucial it is to acknowledge and consider the various cultural, social, and infrastructure realities that influence mobility requirements and practices in various geographical areas. A more nuanced and holistic approach is essential to design urban transport systems that deliver tailored benefits to individual contexts, ensuring equitable and effective mobility solutions for all cities, regardless of their development stage.

Given that MaaS involves integrating diverse transport services, future research should focus on tailoring MaaS packages to align with the unique preferences and needs of potential users, considering the specific characteristics of each context. Moreover, expanding the scope of MaaS beyond mobility services and including “non-mobility” services such as home delivery should provide better insights into what people really want as a mobility solution, as it could encompass more than commuting-related services. This was also a limitation of this study, as it accounted only for commute satisfaction, whereas considering well-being would provide a more holistic view.

While the findings offered by this study may provide valuable insights into the intentional factors and predecessors regarding MaaS adoption in different geographical and socioeconomic contexts, it should be acknowledged that there are several limitations that should be considered when interpreting and applying the results.

First, the sample sizes and data collection methods varied, which may impact the generalizability of the study. For instance, despite efforts to represent the population in all cities, the use of convenience sampling may have introduced selection biases. Second, as the survey was predominantly distributed online, it limited the ability to collect representative data from elderly respondents, restricting insights for this demographic segment.

Third, the study provides a snapshot of current attitudes and behaviors toward MaaS but does not examine how these may change over time, presenting an opportunity for future research as transport systems and MaaS offerings continue to evolve. This limitation is common in cross-sectional designs, which, while not diminishing their contributions, raises the need to interpret the study outcomes with caution (Savitz and Wellenius, 2023; Wang and Cheng, 2020).

Lastly, while the diversity of cities included is a major strength of this study, it neither fully captures the range of urban environments globally nor encompasses the complete set of psychosocial and cultural variables that may explain intention-related differences. In this regard, I encourage other researchers to explore, perhaps through complementary research designs (e.g., qualitative and mixed-method studies), the role of socio-cultural traits, values, and transport justice dynamics in shaping MaaS acceptance, usage patterns, and its potential contributions to transport justice and sustainability in different regions.

Chapter 6: Different cities, different needs? A cross-sectional study on MaaS bundles preferences

This chapter was partially presented and published at the International Transport Forum Summit 2025. Mauricio Orozco-Fontalvo, María Santos Alfageme, Óscar Oviedo-Trespalacios, Sergio Useche, Sylvia Y. He, Sonia Mangones, Marc Hasselwander, Margareth Gutiérrez, Ana Karina Christ, Hannah Hook, Mohammed Abouelela, Lenin Bulla-Cruz, Jorge Bolívar-Redondo, Filipe Moura.

Summary

This chapter builds on the intention to use and goes deeper to investigate user preferences for MaaS bundles across nine cities with varying levels of transport system integration, using the IMPReSS framework as a basis for comparison. By applying a clustering approach and aggregating service rankings via Borda count, identifying distinct urban mobility profiles and derive tailored MaaS packages that align with local conditions. The results reinforce the inadequacy of a one-size-fits-all model. Public transport remains a core component in more integrated systems, while ride-hailing consistently ranks highly across all contexts, highlighting its value in bridging service gaps. In contrast, car-sharing and moped-sharing show limited appeal regardless of system integration. Importantly, informal and locally embedded services such as motorcycle taxis emerge as vital components in less integrated contexts, showing the need to consider informal mobility in MaaS strategies. Finally, the study critiques the Global North–South dichotomy often used in mobility research, advocating instead for context-sensitive frameworks like IMPReSS to inform more equitable and responsive MaaS policy and design. The results provide a foundation for future research and policymaking aimed at creating more inclusive, adaptive, and user-centered urban mobility systems.

6.1 Introduction

The definition of which services should be included in MaaS bundles has been a topic of debate since the concept was first introduced in 2014. While integration is the core promise of MaaS, and users should be able to freely choose any transport service (Lajas and Macário, 2020), the question of *what* should be integrated remains unresolved. This uncertainty presents a challenge for both researchers and policymakers, as it complicates efforts to design attractive and viable MaaS offerings that reflect users' real mobility needs (Butler et al., 2021c).

To address this, a growing body of literature has attempted to analyze MaaS bundle preferences (Ho et al., 2021; Krauss et al., 2023; Kriswardhana and Esztergár-Kiss, 2025). However, most of these studies rely on predefined bundles, limiting users' input to a set of pre-selected options. This approach risks overlooking users' actual priorities and disregards the contextual differences that shape transport behaviour. As a result, findings are often not transferable across cities with distinct mobility landscapes, regulatory environments, or levels of transport network maturity.

This chapter builds on previous findings, particularly those from Chapter 5, which demonstrated that MaaS acceptance is shaped by both social-psychological factors and local conditions, and called for flexible, context-sensitive implementation strategies**.** Here, I expand this line of inquiry by inviting users to design their own MaaS bundles. Rather than constraining them with pre-selected packages, a wide array of transport and non-transport services is provided to analyze the budget allocation patterns that emerge. This allows us to assess which services are most valued, and under what circumstances, to be able to reply the question ***Is a universal MaaS bundle feasible?***

The research addresses a critical gap in the MaaS literature, namely the lack of empirical, comparative data on user-defined bundle preferences across diverse urban settings—particularly in the Global South, where MaaS research remains limited (Hensher et al., 2021; Krauss et al., 2023). The sample includes nine cities: four in Latin America, two in Asia, and three in Western

Europe, representing a range of mobility patterns, institutional contexts, and levels of transport system maturity. To account for these structural differences, cities are classified using the IMPReSS framework (Chapter 4), which captures the integration, multimodality, policy coordination, and readiness of local transport systems.

This chapter seeks to assess how the unique characteristics of cities shape users' readiness to adopt MaaS and influence the way they compose service bundles. It also aims to identify bundle configurations that are more reflective of local preferences, offering a more grounded basis for future pre-defined MaaS packages. Moreover, it explores the attractiveness of integrating non-personal mobility services, such as home delivery and parcel delivery, into MaaS offerings as they have become an increasingly relevant consideration in evolving urban contexts. Specifically, explore (1) which transportation services users consider essential for inclusion in a MaaS bundle, (2) whether a set of standardized, pre-defined bundles can satisfy diverse user needs, and (3) the extent to which these bundles perform consistently across varying urban contexts. The results have practical implications for MaaS operators seeking to develop user-centered offerings and for public authorities interested in ensuring context-appropriate policy design.

This chapter is organized into four main sections. Following this introduction, the Methodology section details the data transformation and ranking procedures, including the clustering analysis used to identify distinct user segments. The Results section presents the key findings, with a dedicated discussion of their implications for practice and future research. Finally, the Conclusion synthesizes the chapter’s contributions and outlines possible avenues for further exploration.

6.2 Literature review

Several studies acknowledge how MaaS research has tended to overlook Global South realities and try to bridge this gap (Ahmed, 2025; Dzisi et al., 2023; Hasselwander and Bigotte, 2023; Núñez and Antoniou, 2025). Most papers share findings on the barriers to implementing fully integrated MaaS systems and tend to agree on aspects related to digitalization (Ahmed, 2025; Núñez and Antoniou, 2025), integration of mobility services (Hasselwander and Bigotte, 2022; Singh, 2020), and public governance challenges (Dzisi et al., 2023; Hasselwander and Bigotte, 2022; Lajas and Macário, 2020)

Most papers argue that insights from MaaS research in the Global North may have little transferability to the Global South context. Yet, the extrapolation of the particularities of a single city (Singh, 2020), a single country (Ahmed, 2025), or a handful of cities from one continent (Dzisi et al., 2023; Sovacool et al., 2022) to speak for the entire Global South can unintentionally promote the development of broad generalizations. Moreover, Núñez and Antoniou (2025) create an index to compare countries' readiness to adopt MaaS instead of cities, without explaining the diversity of MaaS systems within the same country or how they aggregate these differences to rank MaaS readiness. This chapter evaluates whether the Global North – Global South narrative serves in the classification of MaaS systems.

Likewise, several authors try to characterize MaaS adoption issues in the Global South by their car dependency (Ahmed, 2025; Hasselwander and Bigotte, 2023)when this is a particular reality that characterizes precisely the other side of the hemisphere (Prieto-Curiel and Ospina, 2024). As pointed out in Chapter 3, MaaS adoption efforts should take a more comprehensive look at potential positive outcomes for a successful application worldwide. In the case of Ahmed (2025), digital literacy (personal innovativeness and technology self-efficacy) is cited as a barrier to MaaS adoption in "developing countries" like Malaysia. However, this is questionable given that Malaysia outperforms several European Union countries (European Union, 2023) in digital literacy, where MaaS is gaining traction.

Recent studies on MaaS predefine bundles without considering user preferences (Ho et al., 2021; Krauss et al., 2023; Kriswardhana and Esztergár-Kiss, 2025). Others (Hasselwander and the other MaaF study) (Hasselwander et al., 2023; Hensher and Hietanen, 2022) mention other additional services that do not involve personal mobility (i.e., delivery services) but do not assess their prioritization within a MaaS bundle. This Chapter, therefore, attempts to bridge a gap in the literature on MaaS bundles by focusing on analyzing user preferences, which may allow for a successful, tailored evolution of MaaS.

6.3 Methodology

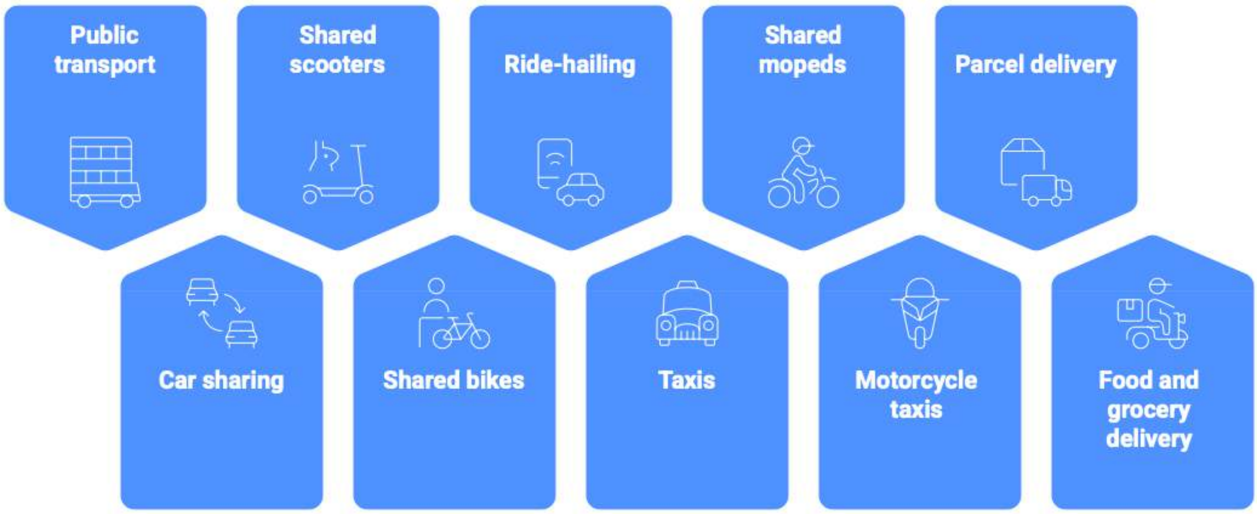
This chapter employed the MaaS bundles section from the MaaS global Survey dataset, spanning nine cities, four in South America, three in Europe, and two in Asia, as presented in Figure 10 (Cairo was excluded from this chapter as their survey version omitted this section). Based on the Buy-a-Feature design thinking technique (Cuofano, 2024), it engaged 3,800 respondents between September 2023 and June 2024; sample characteristics are presented in Table 12. Enabling participants to allocate a virtual transportation budget across ten mobility services to design their ideal transport bundle, it was carefully adapted to each city’s cultural and linguistic context. Translated from English into five languages (Portuguese, Spanish, Mandarin, Arabic, Dutch), the survey produced ten tailored versions that ensured clarity and cultural relevance. The data was initially collected through social media and subsequently through face-to-face interviews in public spaces, to capture perspectives from underrepresented segments and enhance the representativeness of the findings.

Figure 10. Geographic Distribution of Surveyed Cities

Respondents were asked to state their weekly transportation costs, including parking and tolls, if applicable. Participants were then prompted with the following question: "How would you allocate your transportation budget percentage-wise among the following services?" (Figure 11), using interactive sliders to construct their ideal transport bundle among ten different mobility services (Figure 12).

Figure 11. Budget allocation example

Figure 12. Services presented



The analytical approach aimed to identify distinct profiles of mobility bundle preferences and rank the importance of different transport services within each group. The process consisted of two main stages: first, clustering individuals based on their preferences for transport service allocation, and second, computing aggregate service rankings using the Borda Count.

6.3.1 Data transformation and ranking

The percentages allocated to each service were treated as indicators of individual preference. To enable clustering based on relative preferences rather than absolute values and to reduce heterogeneity, each respondent's allocation vector was converted into a rank vector. Services were ranked in descending order of allocated budget, with rank 1st corresponding to the most preferred service. This transformation was done using the rank package in R, and the ties method employed was "average" to balance fairness.

6.3.2 Clustering of bundle preferences and Borda count

To identify bundle preferences, a comparative analysis between Global North and Global South cities was conducted. However, the statistical tests revealed no significant differences in bundle preferences based on this classification. Then, I performed an individual city-level analysis and observed patterns that led us to hypothesize that the similarities in preferences were more closely related to the maturity of the transport network than to the cities' geographical locations. To test this hypothesis and enhance both replicability and the understanding of bundle preferences, the cities were grouped according to their level of MaaS maturity, using the IMPReSS method as a proxy.

Given this, I applied hierarchical clustering, and a fixed number of three (k=3) clusters was used in each IMPReSS level to ensure comparability (Chapter 4). Table 20 shows the classification of cities according to the IMPReSS methodology. Each individual was assigned to a cluster based on the cut of the dendrogram at level 3. The resulting clusters represent groups of respondents with similar prioritization of services included in a MaaS bundle. After clustering, the Borda count was applied, a positional voting rule to transform individual rankings to a collective ranking that would represent the most suitable bundle for each cluster.

Table 20. Classification of cities according to IMPReSS methodology

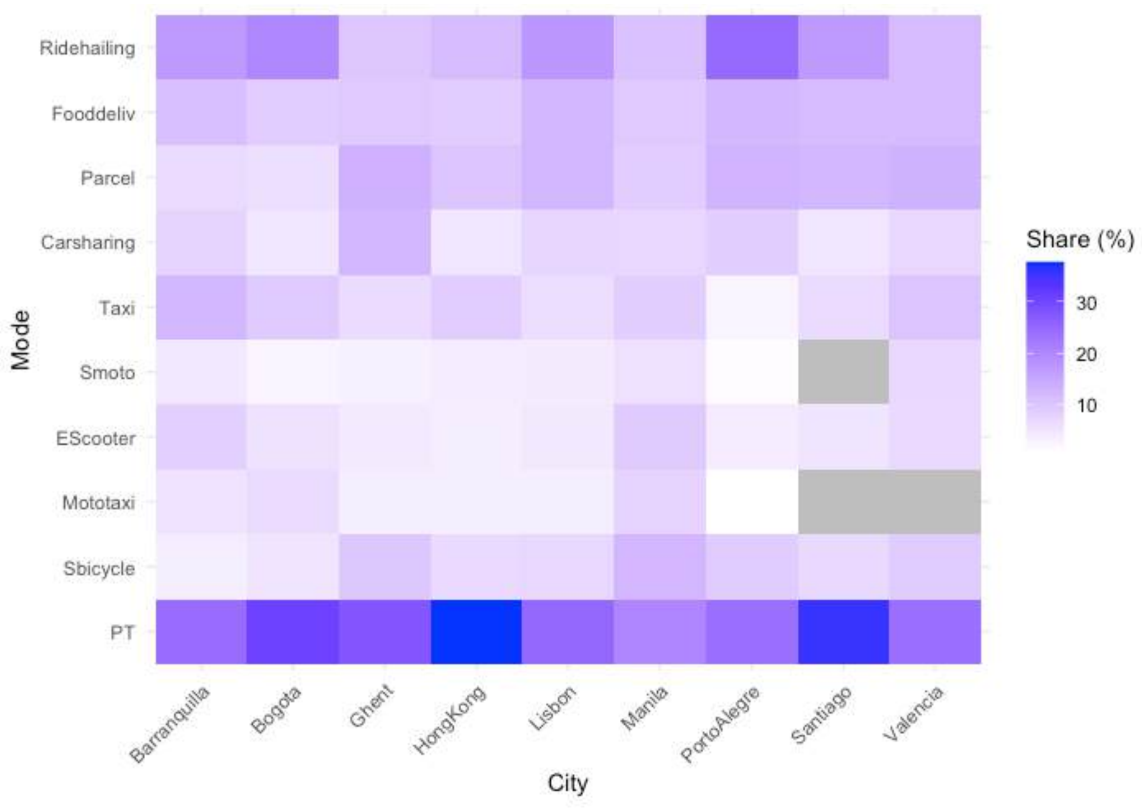
IMPReSS Level	*Cities*
High IMPReSS	Ghent, Hong Kong, Lisboa, Valencia
Medium IMPReSS	Porto Alegre, Santiago, Bogota
Low IMPReSS	Barranquilla, Manila

To conduct the Borda count, the frequency of each service of each rank was computed, and each rank *r* was assigned a point value *(N-r),* where *r* is the total number of services (10 in our case). Meaning that the higher ranks (those with lower numerical values) contribute more points. The final score for each service within each cluster was calculated by multiplying the points by the frequency of the service being assigned to that rank. Scores were summed across all ranks to obtain a Borda score per service within each cluster. Finally, services were ordered in descending order to obtain the cluster-level ranking. Each of the obtained clusters represents a potential MaaS bundle.

6.4 Results

The weighted average allocation results are presented in Figure 13. The analysis reveals that public transport consistently remains the backbone of MaaS services, receiving the largest budget allocation in eight of the nine cities studied. However, preferences diverged sharply for the rest of the services. In Barranquilla, Bogota, Lisbon, and Santiago, ride-hailing services ranked second, highlighting local challenges related to public transport reliability and safety. Conversely, shared micromobility services were ranked lower than anticipated in almost all cases, challenging prevailing assumptions in current policy debates.

Figure 13. Heatmap of service allocation per city



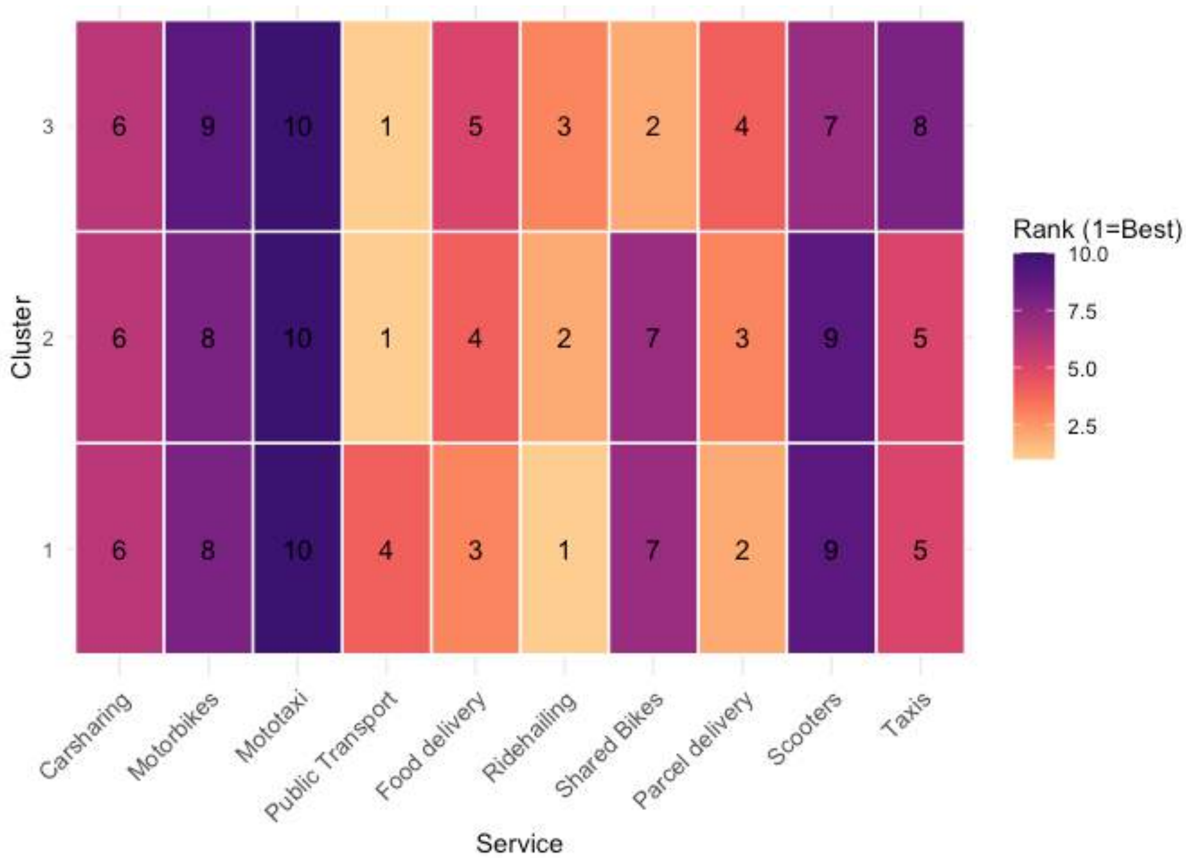
The clustering results allowed us to generalize the findings by proposing prefixed MaaS offerings based on the IMPReSS level of the city where the service would be implemented. The following heatmaps visualize the final rank assigned to each of the ten services within each cluster based on

Borda score results. This analysis allowed us to examine both intra and inter-city variability in service preferences and improve context-based bundle design. For improved interpretability, the clusters were named according to the "urbanite" profiles most likely to adopt the respective bundles.

6.4.1 High IMPReSS bundles

In cities with a high IMPReSS score, three distinct user clusters were identified: *Comfort First Motorist* (32%, Cluster 1), *Micromobility Skeptic* (45%, Cluster 2), and *Eco-multimodal* (23%, Cluster 3). Public transport ranks first in two of the three clusters, highlighting its central role in meeting daily mobility needs in cities with mature and integrated transport systems (Figure 14).

Figure 14. High IMPReSS bundles



There is also a clear interest in home delivery services, particularly food and parcel delivery. In one cluster, food delivery is ranked even higher than public transport, while in another, parcel delivery appears among the top three. These findings suggests that home delivery services are becoming increasingly integrated into the everyday lives of residents, likely due to their convenience and time-saving potential.

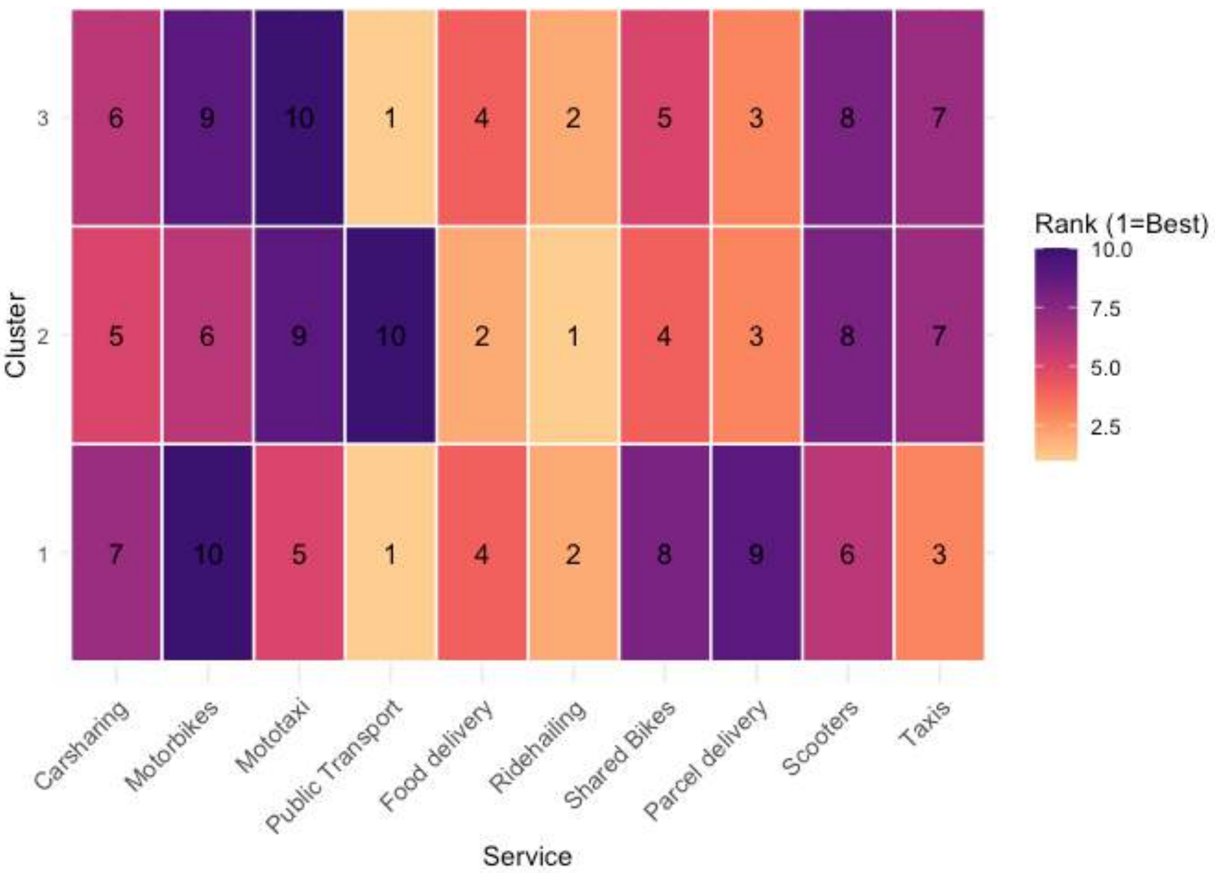
The largest cluster, the *Micromobility Skeptic,* comprising 45% of respondents, ranks micromobility services among the least preferred. Considering these are high IMPReSS cities, the result likely reflects concerns about safety, comfort or convenience rather than service availability or integration. Interestingly, ride-hailing services are strongly preferred, ranking first, second, and third across the three clusters, including among the Eco-Multimodal group. This points to ride-hailing's complementary role, particularly for niche needs such as off-peak travel or areas underserved by public transport.

In contrast, car-sharing ranks consistently low, placing sixth in all three clusters. Its limited appeal may be due to low perceived utility, insufficient coverage, or competition from more flexible alternatives such as ride-hailing.

6.4.2 Middle IMPReSS bundles

In cities with medium IMPReSS scores, greater variability in service preferences emerges across the clusters. The user types identified were Convenience-Driven (49%, Cluster 1), App-Based Individualist (14%, Cluster 2), and again Micromobility Skeptic (37%, Cluster 3). Public transport continues to be important, ranking first in two clusters but falling to last place in the third (Figure 15). This suggests that while a majority still values public transit, a significant minority actively avoids it, likely due to perceived issues related to reliability, perception, integration, or comfort.

Figure 15. Medium IMPReSS clusters



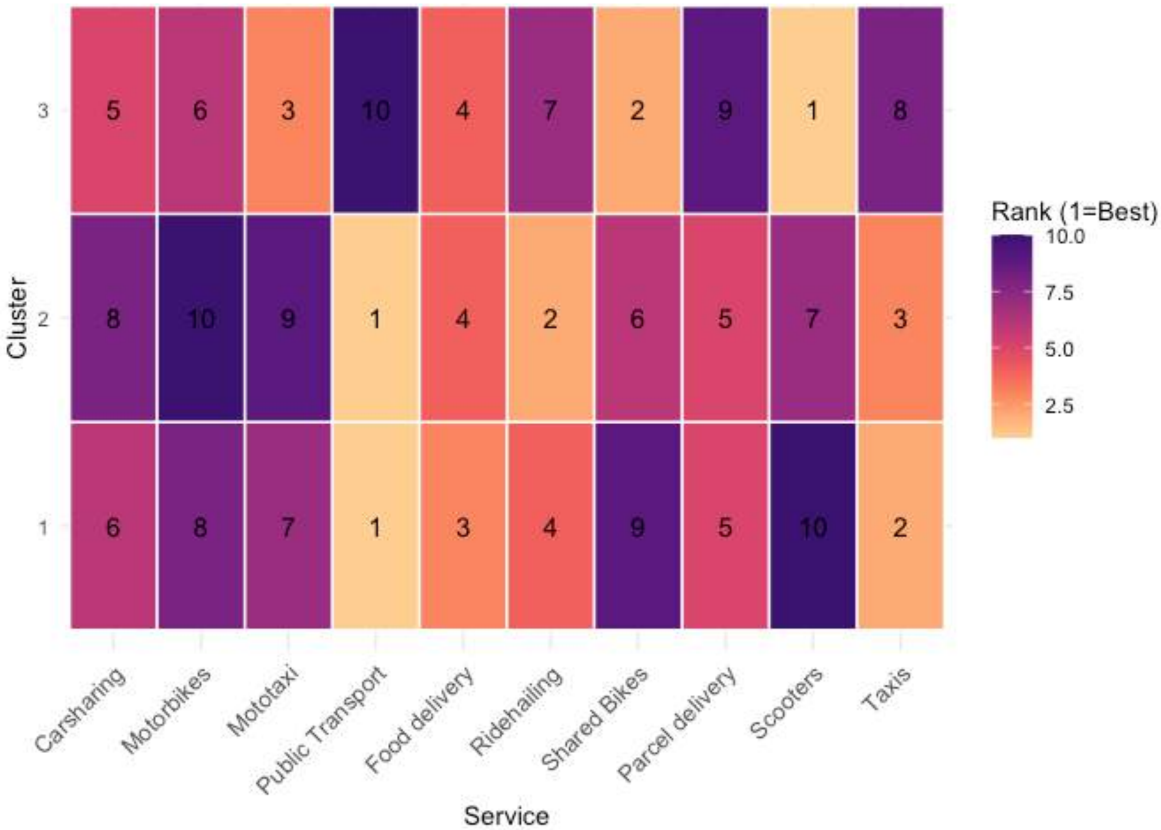
Food and parcel delivery services remain relevant, although parcel delivery is ranked as low as ninth in Cluster 1. Ride-hailing on the other hand, maintains a dominant position across all clusters, ranked first in one and second in the remaining two. This consistency reinforces its centrality in MaaS offerings for medium IMPReSS cities. Car-sharing again ranks low across all groups, suggesting it should not be prioritized in MaaS design in cities with only partially developed transport systems

Micromobility services also continue to struggle for preference. The *Micromobility Skeptic* cluster comprises 37% of respondents, indicating that these services are still not perceived as attractive or convenient options. This result challenges the assumption that micromobility will naturally complement public transport, and aligns with prior findings from cities such as Paris, Santa Monica, Austin, among others, where its usage is associated with leisure rather than commuting (Orozco-Fontalvo et al., 2022).

6.4.3 Low IMPReSS bundles

The analysis of low IMPReSS cities reveals marked differences compared to the other groups. As presented in Figure 16 the urbanite types were: *Micromobility Skeptic* (44%, Cluster 1), the *Convenience Driven* (34%, Cluster 2) and a new and particular profile: the *Two-wheeler Lover* (22%, Cluster 3). Similarly to the medium IMPReSS, Public transport ranked first in two of the cluster but last in the other. Notably, motorcycle taxis rank as the third most preferred service in Cluster 3, marking a significant divergence from trends observed in more mature transport settings. This result highlights the importance of informal or semi-formal transport solutions in contexts where public transport services and infrastructure may be insufficient, unreliable, or unsafe.

Figure 16. Low IMPReSS bundles



Contrary to the medium and high IMPReSS groups, parcel delivery services are not highly valued in low IMPReSS cities. Food delivery remains relevant but is ranked only third and fourth. These lower rankings could be due to limited platform coverage, affordability constraints, and undeveloped logistics infrastructure, all of which may impact reliability and perceived usefulness. Ride-hailing are less dominant in this group, with taxis achieving similar rankings. This suggests that in this context, traditional taxi service continue to hold a competitive role. Car-sharing however, remains a non-priority service, mirroring the trend in the other groups.

The emergence of the *Two-wheeler Lover* profile, highlight the need to consider informal (popular) transport options in areas with low access to the transport system. This type of urbanite may also reflect a higher risk tolerance or a greater need for flexibility and congestion avoidance, which two-wheeled vehicles such as motorcycles taxis can provide despite infrastructure limitations.

6.5 Discussion

The results offer a valuable foundation for reflection and offer an evidence-based starting point for decision-making and the design of MaaS bundles. This discussion centers on eight key insights: (1) the perception of micromobility across IMPReSS levels; (2) the role of home delivery services within MaaS; (3) the central role of public transport; (4) the importance of ride-hailing and (5) popular transport; (6) the different perceptions of taxis in the urban mobility landscape; and (7) the limited appeal of car-sharing and moped-sharing options; and finally (8) the limitations of Global North-Global South classifications for understanding urban mobility services.

6.5.1 Micromobility rejection across contexts

One of the main findings is the ubiquity of the *Micromobility skeptic* urbanite across all IMPReSS levels, representing nearly half of the respondents in each context. This suggests that the low attractiveness of micromobility services is not simply due to limited availability or integration, but may instead be driven by deeper behavioral, perceptual or contextual barriers, such as perceived convenience (Orozco-Fontalvo et al., 2024a), concerns about safety (Félix et al., 2023) or resource constraints (as discussed in chapter 8). For transport authorities and operators, this highlights the necessity of dedicating resources to infrastructure development, regulation and user education before expecting widespread uptake of micromobility offerings within a MaaS ecosystem.

6.5.2 Expanding MaaS scope with Home Delivery Services

Another original finding of this study is the prioritization of home delivery services (both parcel and food delivery), which consistently ranked second or third in across groups. When combined, they even surpass public transport allocations. These services are rarely considered in MaaS design frameworks (Ho et al., 2021; Matyas and Kamargianni, 2019) and have been largely ignored in more recent studies (Kriswardhana and Esztergár-Kiss, 2025). Yet, their inclusion aligns with the evolving shift towards "Mobility-as-a-Feature" (MaaF) model (Hensher and Hietanen, 2022). For stakeholders, this signals an opportunity to broaden the scope and relevance of MaaS. However, this should be carefully addressed given the risks associated with these services (Useche et al., 2024). Intriguingly, if safety concerns underlie the rejection of micromobility but delivery services remain popular, it may indicate a distancing from risk when it is outsourced to gig workers, a paradox worth exploring in future studies.

6.5.3 Public transport centrality and its challenges

Unsurprisingly, public transport serves as the backbone of MaaS packages in the majority of cases, ranking first in two out of three clusters across all IMPReSS levels. This aligns with previous literature that views PT as central to MaaS success (Matyas and Kamargianni, 2019). However, its ranking as the least preferred service by one user group in both medium and low IMPReSS groups signals persistent challenges of network reliability, safety and coverage. Addressing these gaps is critical for improving the perception and trust of the service.

In particular, the role of public transport within a MaaS ecosystem deserves further examination. Hasselwander and Bigotte (2023) showed that, in some contexts, public transport may be valued more by users when combined with shared mobility services and posed the question as to whether the availability of alternative modes (i.e. ride-hailing or electric scooter sharing) would diminish its attractiveness. The results show that respondents do not seem to prefer combinations involving shared micromobility but instead consistently favor pairing public transport with ride-hailing services.

6.5.4 Ride-hailing as an essential complementary service

Ride-hailing emerged as a near-universal preference across all contexts, ranking within the top three services in most clusters. Its perceived flexibility, availability and convenience make it an ideal complement to public transport for first/last mile, off-peak travel or specific destinations/motives. The results indicate that ride-hailing and public transport should be the foundational elements of any MaaS bundle.

6.5.5 Popular transport reclaiming space in MaaS

In low IMPReSS contexts, a particular Two-*Wheeler Lover* profile emerged, ranking moto-taxis and scooter services among their top preferences. This demonstrates relevance of these services in regions where formal options cannot always meet users' needs and that ignoring it or prohibiting is maybe not the best alternative as they are also main transport mode in several cities (Cervero and Golub, 2007; UNDP and GNPT, 2024). Policymakers must therefore develop regulatory frameworks that enable safe and effective integration of these services into MaaS platforms, while future research should address the institutional and technological challenges such integration entails.

6.5.6 Taxis remain a resilient option

While often overshadowed by ride-hailing in high IMPReSS contexts, taxis remain a preferred service in cities with low and medium IMPReSS cities. This suggests that in places where ride-hailing platforms are less prevalent, traditional taxis still hold user trust. Moreover, the fact that in some cities taxi drivers also operate within ride-hailing platform makes them a resilient service that should be considered in bundle design.

6.5.7 The marginal role of car and motorcycle-sharing

Car-sharing and motorcycle-sharing ranked among the least preferred options across all contexts. This contradicts the common assumption that MaaS should necessarily involve car-based shared services. The reasons for this result should be further explored in future works, as it could be related with car ownership or unfamiliarity, lack of availability or the burden of driving and parking. In high IMPReSS cities their marginal role could stem from the existence of well-integrated transport networks and car use constraints or policies and could be seen as a rare option or only viable in punctual cases. These findings suggests that MaaS bundles should be designed based on context-sensitive preferences rather than prescriptive notions of what “should” be included.

6.5.8 Beyond the Global North-South divide

Finally, these findings challenge the relevance of the Global North – Global South classification as a framework for understanding mobility preferences. As noted in section 5.2.2, cities classified within the same geopolitical block often exhibited different patterns in service preference. This shows that traditional binaries fail to capture the complexity of urban mobility systems as within both latitudes there are significant differences in the degree of integration and development of the transportation network (e.g. Hong Kong vs Barranquilla). The IMPReSS classification offered a more useful lens and rationale MaaS bundle proposals., grounded in the level of integration of the transport network rather than broad geographic assumptions. For policy implications, this means shifting from symbolic categorizations to evidence-based frameworks that reflect on-the-ground realities, thereby missing out both on business opportunities and city transformation towards more sustainable transport options.

6.6 Conclusions

This study demonstrates that Mobility as a Service (MaaS) cannot succeed as a rigid, one-size-fits-all model. Its effectiveness and resilience depend on recognizing the unique mobility ecosystems and context-specific needs of cities. Using the IMPReSS framework to classify cities by the level of integration of their transport systems, this study provides a baseline for defining and evaluating tailored MaaS bundles and highlights the value of user segmentation for aligning service offerings with local realities.

Three key insights emerge from the analysis. First, public transport remains a foundational mode, particularly in high and medium IMPReSS cities, where it consistently ranks among users' top preferences. However, its low ranking among certain user groups in medium and low IMPReSS cities points to persistent challenges related to service reliability, coverage, and safety. These differences reflect important spatial inequalities that affect trust in public transport and suggest the need for targeted improvements before expecting it to serve as the central component of MaaS. Second, ride-hailing services emerged as a consistently preferred option across all city types. Their strong ranking highlights the importance of flexible, app-based solutions that can fill service gaps and support first- and last-mile connectivity. Ride-hailing should therefore be considered a core element in MaaS bundle design, particularly in areas where other services are limited or fragmented.

Third, informal and locally embedded services, such as motorcycle taxis, play a key role in the mobility ecosystems of low IMPReSS cities. The emergence of a “Two-Wheeler Lover” user cluster emphasizes the practical importance of these services, especially where conventional options are not reliable. Policymakers should explore regulatory strategies that enable the integration of such services, recognizing their significance in enabling everyday mobility. This study also reveals the limited appeal of car-sharing and moped-sharing services, which consistently ranked low across all contexts. These findings challenge the assumption that such services are essential to MaaS.

Looking ahead, the successful implementation of MaaS will depend on coordinated action by transport authorities, inclusive and user-aligned service design, and ongoing collaboration with mobility providers. MaaS should not be seen merely as a digital innovation layered onto existing infrastructure. Rather, it represents an opportunity to redesign urban transport systems into more inclusive, flexible, and user-centered networks. As discussed in Chapter 3 aligning digital mobility innovations with local contexts is key to creating a resilient offering.

Regarding the limitations, this study is based solely on stated preference data with a limited sample, which may not fully reflect actual behavior or usage patterns. The Borda count aggregation method simplifies preference comparisons but may overlook fewer common preferences that are nevertheless important. Moreover, cultural norms, sociodemographics, and regulatory frameworks were not directly considered but could significantly shape service acceptability and availability. Future research should expand on these findings by incorporating behavioral data, tracking how preferences evolve as services change, and examining the influence of socio-demographic factors on service choices. Further applications of this framework in diverse urban contexts will be crucial to refining global MaaS strategies and ensuring they reflect both user needs and infrastructure realities.

Chapter 7: Should MaaS bundles include home delivery services?

This chapter was partially presented and published in the EWGT 2024 proceedings: Orozco-Fontalvo, M.; Moura, F. (2024), Should MaaS bundles include home delivery services? Euro Working Group in Transportation 2024, Lund, Sweden.

Summary

Based on the results presented in Chapter 6, in this chapter I explore the potential of including home delivery services into MaaS bundles, expanding its reach beyond personal mobility services. Integrating these services into MaaS has received limited attention despite their rising demand. Employing the "Buy-a-feature" prioritization model, coupled with exploratory analysis and generalized linear modeling, I assess respondents' preferences and psychological factors influencing their allocation of transportation budget to home delivery services. Results indicate significant interest in home delivery services among respondents, particularly among employees, women, individuals with higher transportation costs, and those perceiving insecurity or harassment risks. Surprisingly, teleworkers and individuals experiencing psychophysical strain show lower inclinations towards it.

7.1 Introduction

Hensher & Hietanen (2022) propose a market-driven evolution from MaaS to MaaF Mobility-as-a-Feature, advocating for bundles comprising not only mobility services but also including features such as insurance, aiming for holistic financial sustainability. Following the "as-a-feature" trend, a feature that has been relatively overlooked is home delivery services, which, by being integrated into mobility bundles, would replace trips for purchasing food, groceries, or retail items. These services have witnessed a surge in demand, particularly during the COVID-19 pandemic, as people prioritized social distancing (Apouey et al., 2020). Moreover, their growth trajectory has been evident for over a decade, paralleling the rise of the gig economy (Oviedo-Trespalacios et al., 2022; Useche et al., 2024). Incorporating these services into MaaS or MaaF bundles holds significant potential to enhance the value proposition for users and attract interest from major corporations. I hypothesize that given the rise of telework, congestion, availability, and convenience of these services, people would be willing to prioritize its inclusion in their bundle over other mobility services. This chapter aims to answer the following question ***Should MaaS include more than personal mobility services?*** If so: Q1.2: Are potential users interested? If so: Q1.2: Who would be interested in it?

This study aims to assess the attractiveness of broadening the range of services offered in a MaaF bundle, including home delivery services such as food, groceries, and retail shopping. To achieve this objective, the data from Lisbon from the MaaS global survey was used, utilizing the "Buy-a-feature" prioritization framework (Cuofano, 2024). Subsequently, an exploratory analysis of the results was conducted, followed the estimation of a generalized linear model to identify the factors that explain the allocation of these services.

Lisbon was chosen as a case study because it already fully integrates most transportation modes under a monthly subscription that provides unlimited trips, putting the city ahead of many cities in creating a complete MaaS system. At the same time, several platforms offer food and grocery deliveries, as well as plenty of online shopping sites, similar to most European capitals. Following this introduction, Section 2 outlines the methodology. Section 3 presents the results, which are then discussed in Section 4. Finally, I conclude the Chapter with a summary of the findings and suggestions for future research.

7.2 Methodology

Using data from Lisbon extracted from the MaaS global Survey dataset, specifically the Buy-a-feature section (same as Chapter 6), which allows users to “buy” or allocate virtual budget or credit points to different features or services they consider important, this design thinking technique is a collaborative decision-making tool widely used for product development or enhancement based on stakeholders preferences or constraints, as it allows for prioritizing, focusing or identifying the most relevant features of a product/service (Cuofano, 2024**)**.

To avoid bias in the allocation process, the services were presented in a random order to each respondent (Figure 11). The Multimodal Commuting Stress Scale (Useche et al., 2023) was also included to evaluate whether psychological factors related to stress during commuting influenced budget allocation to home delivery services.

For the data collection, the Lisbon dataset from the MaaS global survey collected more than 1,200 responses. However, a final sample of 806 responses was obtained after the responses' validation process. Table 21 presents the summary of the main sociodemographic characteristics of the sample.

Table 21. Sample characteristics

Variable	Categories	Sample distribution	Population distribution
Gender	Men	41%	48%
	Women	58%	52%

Variable	Categories	Sample distribution	Population distribution
	Non-binary	1%	
	18-24	32%	11%
Age	25-54	59%	42%
	55-65	7%	13%
	65+	2%	21%
	Employee	61%	55%
	Undergrad student	25%	22%
Occupation	Freelancer	4,50%	-
	Business owner	4,50%	-
	Other	5%	-
	Less than €900	5.98%	12%
	€901-€1500	19.55%	17%
	€1501-€2500	33.50%	30%
Income	€2501-€4000	26.28%	30%
	€4001-€7000	11.46%	11%
	More than €7000	1.25%	-
	Other	1.99%	

To investigate the integration of home delivery services into MaaS bundles, a Generalized Linear Model GLM with a Quasi-Poisson distribution was employed to estimate the factors influencing the budget allocation to these services. This method was selected because it extends the traditional linear regression, accommodating various response variables with non-normal distribution and relaxing the assumptions and restrictions of multivariate linear regression. This flexibility makes it useful for modeling real-world phenomena such as consumer behavior, as was the case with the home delivery variable within the MaaS framework.

GLMs consist of three main components (Washington et al., 2020). First, the random component defines the probability distribution of the response variable Y, which, in this case, is the normalized sum of the percentages allocated to food, groceries, and parcel deliveries. The dependent variable follows a Quasi-Poisson distribution to account for overdispersion $VarY = \phi\mu$, where ϕ is the dispersion parameter. Second, the systematic component represents the linear predictor η, a linear combination of the explanatory variables that can be expressed as shown in Equation 3.

$$\eta = X\beta, \tag{3}$$

where X is the matrix of explanatory variables, and β is the vector of coefficients. The explanatory variables include sociodemographic, psychological, and travel patterns variables. All variables were treated as dummies except for "Age", Insecurity score, psychological strain score and the weekly transportation cost. Third, the link function connects the mean of the response variable μ= EY to the linear predictor η. The log link for the Quasi-Poisson distribution η= logμ was used. The general form of a GLM is given by Equation 4.

$g(\mu) = \eta = X\beta$, where *g.* is the link function. (4)

The model estimation was performed using the glm function in the base R package. Variables included in the model and their description are presented in Table 22. The dependent variable was defined as the percentage allocated to home delivery services.

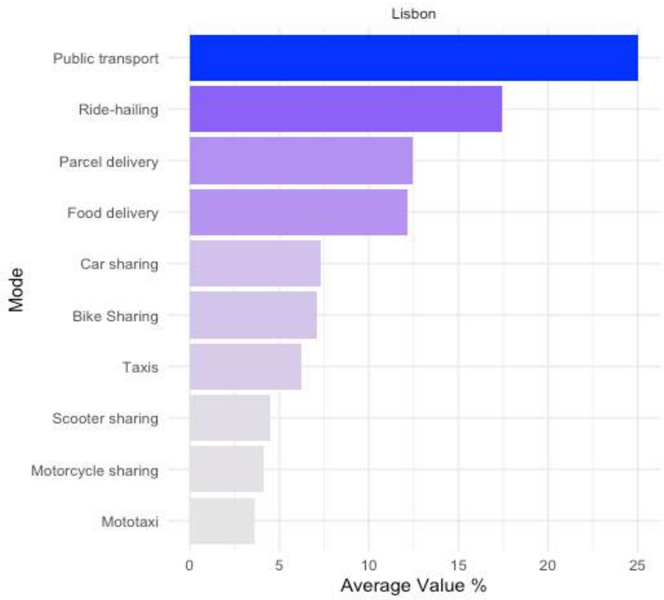
Table 22. Variable description

Variable	Type	Description
Employee	Dummy	If the respondent was an employee
Female	Dummy	If the respondent was a female
F2insecure	Continuous	Mean Insecurity perception score
F4Psytrain	Continuous	Mean Psychological strain perception score
Transcost	Continuous	Weekly transportation costs
Telework	Dummy	If respondent teleworked
Childrendum	Dummy	If there were children in the household
Age	Continuous	Age of the respondent
Car ownership	Dummy	If the respondent owned a car
Home Delivery (Dependent variable)	Continuos	Percentage (0 to 100) allocated to home delivery services

7.3 Results

Results show that 82% of respondents allocated a percentage of their transport budget to food or grocery deliveries and 80% to free retail shipping, which shows that the idea is at least interesting for most respondents. Moreover, Figure 17 shows the results of the average allocation. Notably, parcel and food delivery ranked third and fourth with approximately 13% each, meaning that if we aggregate them as “Home Delivery Services,” they would become the most allocated service with a mean of 24.7% and a standard deviation of 18.8% For the [3]model estimation, I added the allocation given to retail shipping and food delivery to create a variable called "Home delivery."

Figure 17. Average allocation % per service



Regarding the model results in Table 23, all the variables included were significant although some results were unexpected. The model indicates that employed respondents, women, those with higher weekly transportation costs, and those living with children are more likely to allocate the transport budget to home delivery services. Considering the stress variables, those who feel more insecure or have a perceived risk of harassment "F2Insecure" are also more likely to include delivery services in their bundle. Car owners are also interested in these services, which the lack of parking spaces in Lisbon could explain.

On the counter-intuitive side of the results, I found that teleworkers are less likely to include the service. One explanation could be that spending most of the day at home leads individuals to prefer

---

[3] Note: min = 0%, Q1=10%, Q2=20%, Q3%=35%, max=100%, we consider the maximum value obtained to be an outlier, as allocating all the transportation budget to these services is not sensible, still, we decided to keep it because it is still doable.

activities such as shopping, dining out, and grocery shopping. This behavior was observed during the pandemic when restrictions severely limited the ability to go out, as Hook et al. (2023) explained.

Table 23. Model results

Variables	Estimate	Std. Error	T value	Sig
Intercept	3.1123550	0.1324245	23.503	***
Emplodum	0.1327738	0.0599642	2.214	*
GendFem	0.0998244	0.0544980	1.832	.
F2insecure	0.1307935	0.0513939	2.545	*
F4Psytrain	-0.1556937	0.0431199	-3.611	***
Transcost	0.0016734	0.0006936	2.413	*
Telework	-0.2006601	0.1286830	-1.859	.
Childrendum	0.1556711	0.0595782	2.613	**
Age	-0.0047886	0.0022044	-2.172	*
Carown	0.1371475	0.0661212	2.074	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Another interesting result was regarding the psychophysical strain factor, which refers specifically to the emotional stress while commuting e.g., anxiety, frustration, and helplessness. This factor was also negative, meaning the respondents would be less prone to include “Home delivery services” in the MaaS or MaaF bundles. This may be related to the uncertainty of the deliveries and unexpected delays, making people with a higher level of anxiety or stress concerning their mobility patterns prefer to allocate their budget to other services. In the case of Lisbon, food delivery is often delayed, and the delivery time windows for retail shipping and grocery deliveries are usually within twelve hours (Vianna, 2024).

Variables such as income and transportation mode were tested but were not significant, indicating that latent variables may better explain the distribution of the transportation budget regarding this service. Including these types of services into MaaS or MaaF needs to be carefully reviewed, and wider integration for insight through agreements with supermarkets or retailers must be explored to guarantee the financial suitability of the system. On the other hand, it is worth mentioning that the food and grocery delivery services have been criticized because of the working conditions of their delivery riders (Useche et al., 2024). Hence, regulation is key for seamless integration and to avoid future issues that could affect the system.

7.4 Discussion

Building upon the previous discussion of results in Table 23, I add that teleworking emerges as a notable predictor. Although surprising, this observation aligns with previous research indicating that teleworkers, enjoying the convenience of working from home, may perceive less necessity for home deliveries. For example, Khaddar and Fatmi (2024) found that working from home in the post-pandemic era revealed a negative relationship with online food ordering. Conversely, the presence of children in households presents a positive association with increased utilization of home deliveries, corroborating studies highlighting the convenience of such services for busy parents (Van Droogenbroeck & Van Hove, 2017)

Psychological strain, evidenced by stress or anxiety, surfaces as another influential factor, negatively affecting engagement with home delivery services. For instance, Krauß et al. (2023) found that individuals experiencing psychological strain may exhibit a decreased inclination toward adopting MaaS bundles. However, being employed emerges as a positive predictor, potentially attributable to time constraints associated with employment and the consequent desire for convenience, especially when households also have children (Spurlock et al., 2020). On the other hand, respondents with a higher fear of crime during their commute are more keen on using home delivery services, as the sense of insecurity directly impacts their travel patterns (Soto et al., 2022).

Gender also plays a role, with females exhibiting a greater propensity for online shopping and utilizing home delivery services, possibly driven by factors such as convenience and a greater willingness to adopt new technologies (Faqih, 2016). Lastly, higher transportation costs, while positively impacting the propensity to adopt home delivery services, may not be the primary driver of this adoption i.e., much less impact on the propensity to allocate household budget to home delivery services. Such increases potentially prompt individuals to opt for such services as a cost-saving measure, particularly for bulk or heavy items (Spurlock et al., 2020; Visser et al., 2014).

7.5 Conclusions

This research explored the possibility of widening the services offered in a MaaS bundle by considering integrating home delivery services. Results show a high interest in these services, which, despite not being considered in previous studies as mobility services, play a crucial role in the current urban mobility dynamics. Hence, the results suggest offering them as a part of the mobility package options, ensuring a more holistic approach regarding today's mobility needs. Moreover, these results support the idea that MaaS needs further integration with non-personal mobility services as it evolves into a MaaF to attract more users and fulfill its expected potential. However, these results may vary in different contexts, making it necessary to conduct similar studies in other cities with different sociocultural and transportation network characteristics. Using indicators and factor analysis to define latent variables is highly suggested for future research. Also, including spatial variables in the model could prove helpful in explaining the allocation results better.

PART III

Structural Conditions and Governance of MaaS

What regulatory roles and strategic actions should public authorities undertake to effectively govern and implement MaaS?

Sub questions:

1. *Which are the resources needed to access to MaaS?*
2. *How to identify the most suitable role for a public authority in MaaS implementation?*

Chapter 8: MaaS: Which resources are enablers, and who is being excluded?

This chapter is under review as a journal article: Orozco-Fontalvo, M.; Lopes, A.; Vale, D.; Moura, F. (2025), MaaS: Which resources are enablers, and who is being excluded? Transportation Research Part D [Manuscript under review]

Summary

While Part II explored user preferences and revealed encouraging findings regarding intention to use and bundle design, it is essential to take a step back before drawing overly optimistic conclusions. These promising results must be weighed against a more fundamental question: are individuals actually able to access and use MaaS in the first place? Or reframed ***Which are the resources needed to access to MaaS?*** Access to MaaS services is restricted for some population segments due to the spatial availability and to resources like mobile data, digital literacy, or vehicle-riding skills. Moreover, these services are frequently more expensive than traditional modes of transportation, which may contribute to social exclusion. This chapter aims to identify the resources that enable or hinder access to MaaS. These resources were identified from the literature and then included in a survey (n=2000) conducted in Lisbon within the MASTI project. Results indicate that 20 to 30% of respondents lack the necessary resources to use MaaS. Still, Access depends on the type of service, which is significantly influenced by their profile. This chapter highlights the main resources that provide access to MaaS and addresses the importance of providing flexibility for different enablers to increase accessibility.

8.1 Introduction

Much of the existing discussion is about MaaS impacts on urban transport dynamics and socio-territorial inequalities. In her research about Transport-Related Social Exclusion (TRSE) and mobility innovations, Lucas (2019) concluded that the social and equity implications of new mobility technologies are under-investigated, and we still lack an understanding of their effects on disadvantaged groups. In the case of MaaS, there needs to be more evidence on whether people can use it or if its requirements may generate social exclusion. Most studies on social exclusion commonly focus on car users (Chapter 3), ignoring other population segments (e.g., economically disadvantaged, digitally unskilled, etc.). Since most car users already have the resources to use MaaS, ignoring other social and demographic groups indicates a gap in the topic of transport justice.

Lopes et al. (2023) conducted a literature review about MaaS and identified that most papers addressing MaaS are not based on real-world applications. The authors used the ROOW (Resources, Opportunities, Outcomes, and Well-being) approach to determine which characteristics and requirements benefit or exacerbate social goals. In the ROOW approach, resources are not limited to economic factors but encompass all attributes of an individual or household, whether owned or provided by the environment. Examples include car ownership, the availability of cycling infrastructure, or residing in a pollution-free environment (Martens et al., 2019). In the context of Mobility as a Service (MaaS), an additional layer of attributes should also be considered: the digital dimension.

On a globally aging population - more than 12% of the worldwide population is over 60 years old and higher in most developed countries (Ritchie and Roser, 2019) - an increased life expectancy and significant pressure on technological capabilities or digital skills (Iancu and Iancu, 2020) highlights a growing issue of digital exclusion because of its technological design demanding a certain level of digital literacy. However, the elderly are not the only ones affected by the digital aspect. In less affluent countries, the limited digital skills of the so-called “bottom billion” (James,

2021) represent a recognized challenge, potentially restricting access to MaaS. Moreover, within such contexts, transportation costs have been identified as a significant barrier to accessing public mobility systems (Silver et al., 2023), with these barriers expected to be even more pronounced in multimodal systems.

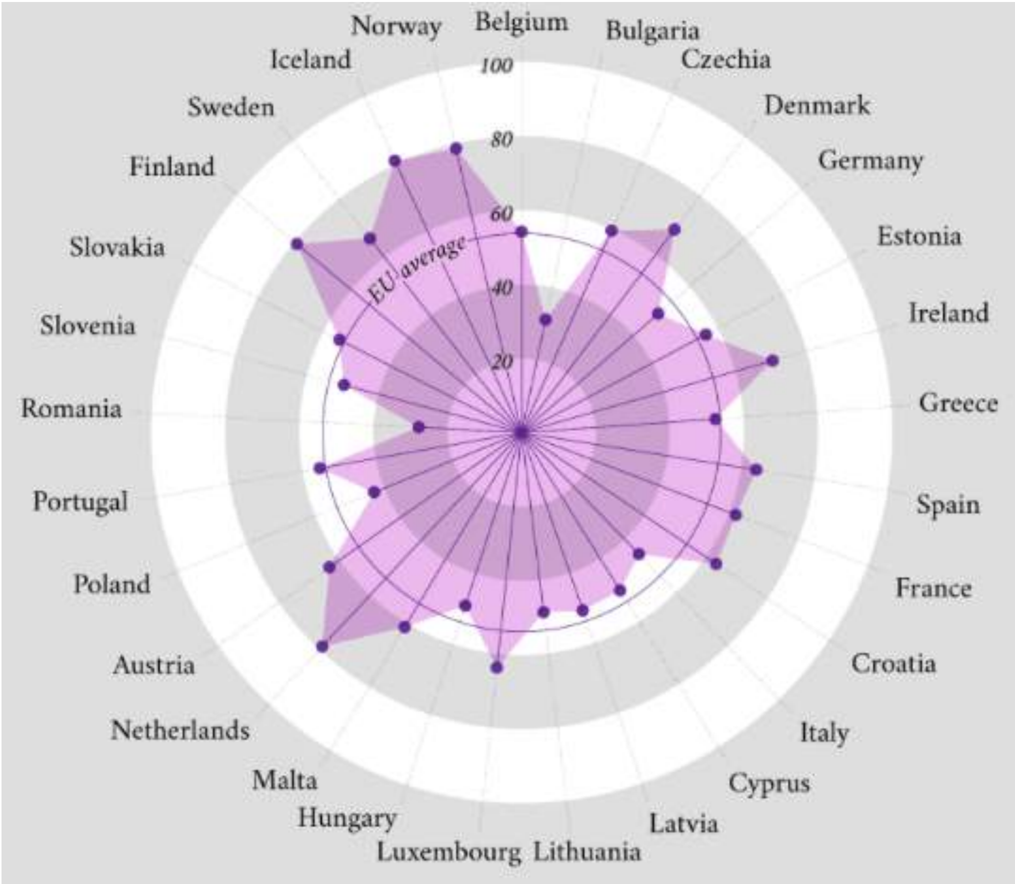
More than assessing MaaS systems outcomes and feasibility, it is important to understand what resources are required to enable access to the proposed systems by distinct population segments or individual profiles. In this sense, and based on the already acquired knowledge about transport inequality and MaaS functionality, I pose the question: ***Which are the resources needed to access MaaS?*** Still, the social impact is unclear, aside from governance and stakeholders' agreement issues. This Chapter focuses on the "Resources" variable from the ROOW framework (Martens et al., 2019), to identify possible barriers needed to access MaaS, analyses the main enablers, and identifying what population segments may be excluded. For this, a specific survey in Lisbon (different and independent from the survey employed in Chapters 5, 6 and 7) was conducted within the MASTI project scope to address this question. The survey inquired about travel patterns and users' experience with new mobility services, namely shared mobility and ride-hailing, using it as a proxy for MaaS use (Arias-Molinares and Carlos García-Palomares, 2020).

After this introductory section, section 2 presents the literature overview on MaaS enablers. Section 3 describes the Lisbon case study, the survey methodology, sample characteristics, and the modeling approach. Section 4 presents the results and the estimated model, highlighting the requirements for different transportation services, followed by the discussion in Section 5. Finally, Section 6 presents this study's conclusion and possible implications.

8.2 Background

While the potential benefits and implementation barriers of MaaS are well-known (Arias-Molinares and García-Palomares, 2020b; Butler et al., 2021c), the literature on what users need to be able to use the service is scarce. This has been likely overlooked in MaaS due to the premise that MaaS inherently improves equity, and because most implementations have occurred in high-income systems with mature transport systems (Caballini et al., 2022; Dadashzadeh et al., 2022), where access to resources is generally not a major barrier. However, several authors have already expressed possible equity issues of MaaS (Kloeke, 2020; Li et al., 2020; Lopes et al., 2023; Storme et al., 2021).Given the lack of resources of some population groups, and its potential expansion to the Global South, it is essential to identify the main prerequisites to use MaaS. Moreover, even within the European Union, the conditions vary, for instance, digital literacy (an important skill to use MaaS) is below 60% (EU average) in 10 of the 27 members (Figure 18).

Figure 18. Individuals with basic digital skills or above in Europe



Source: (European Union, 2023)

This Chapter explicitly focuses on the **Resources** dimension, aiming to identify whether individuals possess the necessary means to use MaaS services in the first place, as understanding whether

MaaS is even accessible is a necessary precursor to assessing preferences, benefits and other **Outcomes**.

For over three decades, the Capability Approach (Sen, 1979a, 1979b, 1974) has emphasized individuals' freedom to achieve well-being as a matter of what people can do and be. Moreover, from a distributive perspective, resources are vital to understanding justice and access (Palmateer and Levinson, 2017). Both the Capability Approach and the "Resourcist" Approach (which prioritizes the distribution of material resources) offer distinct frameworks for assessing well-being and social justice. This study adopts a more generalist approach, drawing from both perspectives, not limited to one framework, but considers both capabilities and resources as critical factors.

Only Dadashzadeh et al. (2022), Li et al. (2020), and Lopes (2023) specifically analyzed MaaS resources from the perspective of social exclusion. Other authors, such as Durand et al. (2022) and Turón (2022), have explored the relationship between resources and social exclusion from the perspective of digital technologies and shared mobility services. These studies highlight several key factors that affect the use of new mobility services, such as digital skills, age, income, physical disabilities, and attitudes. Those more associated with modern mobility services are smartphone possession, spatial access, digital literacy, gender, age, income, and physical (dis)abilities.

From this broad view, four classes of factors were identified, encompassing distinct dimensions related to both material resources and capabilities, both understood as crucial from a justice perspective (Rosano et al., 2009). The material resources are (1) possession of **items** (e.g., smartphone) and (2) **spatial** access (e.g., relative location to MaaS supplied infrastructure). The capabilities are (3) specific **abilities** (e.g., digital literacy, bicycle riding skills) and (4) **individual characteristics**, such as age, income, gender, and physical disability. Considering the transport-related nature of the human activity encompassed in MaaS, the list of factors should contain two additional elements: driving ability plus a driver's license (since MaaS frequently includes rental and shared cars transport mode as an option) and mobile data plan (because MaaS platforms require data to work, and they must be accessed from various locations).

This study incorporates an additional resource consideration: foreign nationality. Foreigners often exhibit distinct travel patterns, demonstrating a higher willingness to walk and reliance on public transport (García-Palomares et al., 2013). Evidence shows that social exclusion and spatial isolation (Chung et al., 2014) hinder access to urban services, particularly for low-income or unskilled foreigners. Many countries restrict the validity of foreign driver's licenses, especially those issued in developing nations, limiting access to some MaaS options such as car or motorcycle sharing. As a first result, the identified primary resources are presented in Table 24, serving as a starting point for us to answer the research question.

Table 24. Factor groups of all identified capabilities and resources that may hinder or improve MaaS adoption

Category	**Resource**	**Description**
Items	Smartphone	Is the cornerstone for mobility digitalization and seen as the primary item that serves as a hindering resource.(Durand et al., 2023; Li and Voege, 2017a).
	Electronic Payment Services	Necessary to acquire online services (Durand et al., 2023; Li and Voege, 2017a).
	Driver License	Is essential for car-sharing and is known to affect exclusion and accessibility levels (Casas, 2007).
	Data Plan	For online services outside the home (Sieck et al., 2021).
Location	Spatial Access	And proximity (Vale, 2020) to and between MaaS options (scooters, bikes,

Category	Resource	Description
		PT, cars, etc.) is vital its usability. Long distances work as a hindrance.
Abilities	Digital Literacy	Required to use new technologies in general terms (Iancu and Iancu, 2020; James, 2021) and specifically within MaaS (Durand et al., 2023, 2022).
	Riding ability	Necessary capacity to use certain modes included in MaaS solutions, such as shared cars, motorbikes and bicycles.
Individual characteristics	Income	Works as an enabler and is highlighted as a critical transport-related social exclusion factor related to MaaS (Silver et al., 2023; Lopes et al., 2023).
	Age	Age groups tend to behave differently regarding travel behavior (Li et al. (2020), Durand et al. (2022), Iancu & Iancu (2020)).
	Gender	Affects the modal choice and MaaS due to safety, riding ability (McIlroy), (2023) and the sexual division of labor (Siqueira et al., 2022).

Category	Resource	Description
	Physical disabilities	May hinder the usability of specific modes (bicycle, scooter, etc.). (Dadashzadeh et al., 2022; Goralzik et al., 2022)
	Foreigners	Endure distinct mobility, social and economic conditions if compared to nationals (García-Palomares et al., 2013), (Chung et al., 2014).

Unlike previous studies that treat MaaS as a uniform system, this research is novel in disaggregating MaaS into its individual services to examine the distinct resource-based enablers and barriers, thereby offering fresh insights into the digital and material requirements that influence equitable access and contribute to transport-related social exclusion.

8.3 Methodology

To assess *to what extent the requirements for using MaaS contribute to transportation exclusion*, three main methodological procedures were conducted: (1) a behavior and resources survey, (2) an exploratory analysis of the collected data, and (3) a structured analysis to explain the impacts of resources and MaaS adoption.

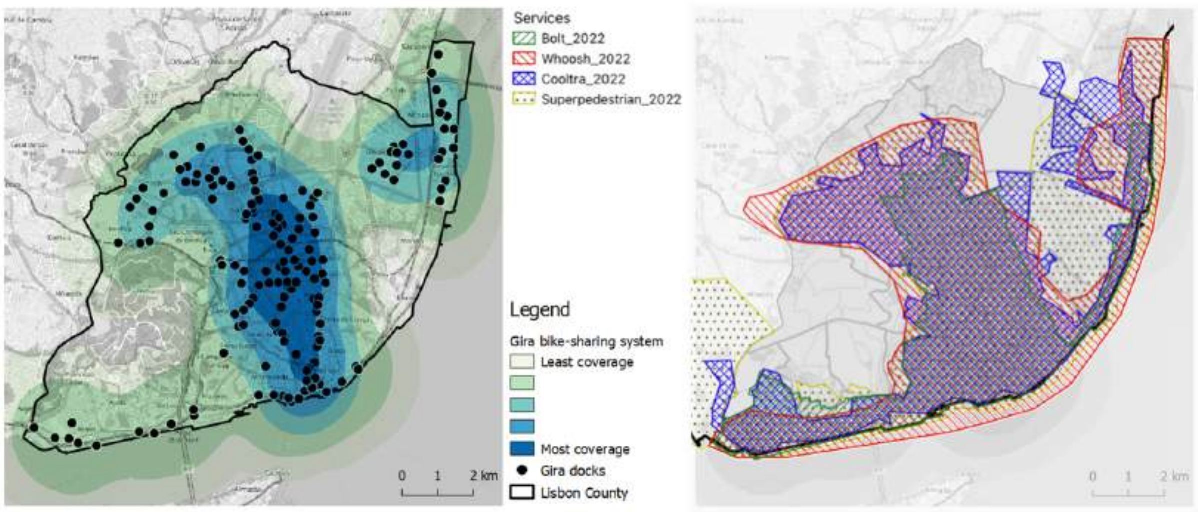
First, developing a questionnaire to capture the necessary data regarding individuals' surrounding conditions, resources, abilities, and mobility decisions concerning available shared modes that typically participate in MaaS solutions (as part of the MASTI project). This survey was derived from the literature review and was conducted in Lisbon, which will be presented in section 3.1. Then, an exploratory analysis was conducted based on the classification of MaaS access levels as a first attempt to answer the posed question. Next, proceeding with a more structured analysis to estimate the role of each identified factor in the level of app-based shared mobility solutions. This analysis tried to overcome the limitations of the exploratory study and was based on the answers collected from the survey applied to a generalized linear model.

8.3.1 Overview of Lisbon and its Multimodal Transport System

Lisbon, the capital of Portugal, has a metropolitan population of approximately 2.8 million people, with 500,000 residing in the city itself. Despite being a popular European destination attracting thousands of young tourists, the city is characterized by a significant demographic trend, with more than 21% of its population aged 65 or older (INE, 2021) and a topography dominated by steep hills. These factors pose substantial challenges to the adoption of shared mobility solutions. The aging population may be unable or willing to engage with such systems. At the same time, the city's hilly terrain restricts the practicality and regular use of active mobility modes. These limitations must be addressed to enhance mobility options. Moreover, digital literacy is estimated around 60%, matching the EU average.

Nonetheless, electric shared mobility witnessed a noticeable improvement in 2022 (Fluctuo, 2022). Evidence of this condition is that, besides the 19 PT operators (among trains, metros, busses, and boats), Lisbon currently holds several ride-hailing (Uber, Bolt, Freenow), shared modes (Gira, E-cooltra, etc.), and micro-mobility operators (Lime, Link, Bird, Whoosh). Gira (Lisbon's shared bike system) is the only public bike-sharing system based on fixed stations scattered over the city. The Gira system counted 161 stations (by July 2024) unevenly distributed over 100 km2 of Lisbon city (Figure 19). The service areas for dockless mobility services are shown in Figure 19 (right). It is a non-exhaustive list, as I've only mapped the major operators illustrating the coverage of these services, as many overlap.

Figure 19. Bike-sharing system coverage (left) and dockless shared mobility services coverage (right).



These two maps show the dock-based bike-sharing system (Figure 19 to the left) and the dockless active-mode services (bikes and scooters) (Figure 19 to the right). By combining both maps, we can understand how the supply of shared transport modes is distributed on the territory. Most are located in the city center (closer to the Targus River, where most tourists are concentrated) and middle- to high-income neighborhoods. Meanwhile, areas at the periphery or predominantly low-income neighborhoods remain underserved. Notably, the dockless services in the eastern zone include some low-income and social housing neighborhoods like Olaias and Chelas (to the East). However, these areas are only served by one operator (Superpedestrian).

8.3.2 Survey Design

The survey was conducted both in person and online between May and July 2022 to collect detailed data on demographics, travel patterns, resources (see Section 2), transportation costs, shared mode usage, and satisfaction levels. To ensure representativeness across key-socio-demographic groups and neighborhoods, a non-probabilistic mixed sampling approach was employed, combining quota and convenience sampling, using both social media and trained pollsters. Pollsters intercepted individuals and conducted face-to-face interviews in public spaces until quotas based on census distributions for age, gender and neighborhood (“Freguesia”) were met.

The survey targeted three municipalities: Lisbon (the capital), Cascais (a high-income area), and Vila Franca de Xira (a middle-to-low-income area). The final dataset included 2144 respondents, with 1856 valid responses after data cleaning. Efforts were made to align the sample with census demographics, such as age, gender, and population density. Table 25 provides an overview of the sample's characteristics and representativeness, highlighting variables such as smartphone ownership, digital literacy, and spatial access to MaaS.

Table 25. Sample characteristics

Resource	Survey	Survey %	Population %	Use Shared modes	Use %
Physical (dis)ability	132	7%	17%*	7	5%
Mobile Data plan	1560	84%	-	256	16%
Trip planner (digital literacy) users	1262	68%	-	238	19%
Elderly > 65	478	26%	22%	4	1%
Low income	316	17%	29%	27	9%
Smartphone owners	1593	86%	-	259	16%
Spatial access	1466	79%	73%	199	14%

We (the MASTI project team) effectively obtained a sample that follows the general trend of census data regarding most demographic characteristics, and the results aligned with existing literature. For example, only 1% of elderly respondents reported using shared mobility services, reaffirming that age is a significant barrier to adoption.

8.3.3 Exploratory Analysis

Before advancing to a more robust analysis, I conducted an exploratory study to categorize access to MaaS. Since MaaS integrates various services into one, I hypothesize that more distinct resources would be needed for an adequate MaaS experience rather than assuming that a set of uniform resources would suffice for a user to benefit from all services. To conduct the exploratory analysis, three categories of access levels to MaaS were considered:

1. **No access**: This applies to users who lack a smartphone, which is indispensable to use MaaS.
2. **Restricted access**: This applies to users who own a smartphone but meet one or more exclusion conditions (e.g., income, lack of riding skills, etc.).
3. **Full access**: Users with all necessary resources and abilities to use the full potential of MaaS.

Certain conditions apply to each mode of transport. If a user does not meet these criteria, access to that mode might be restricted. Table 26 outlines the services considered part of the MaaS solutions and the exclusion conditions (resources and abilities) that limit access to each service.

Table 26. Exclusion conditions per service within a MaaS environment[4].

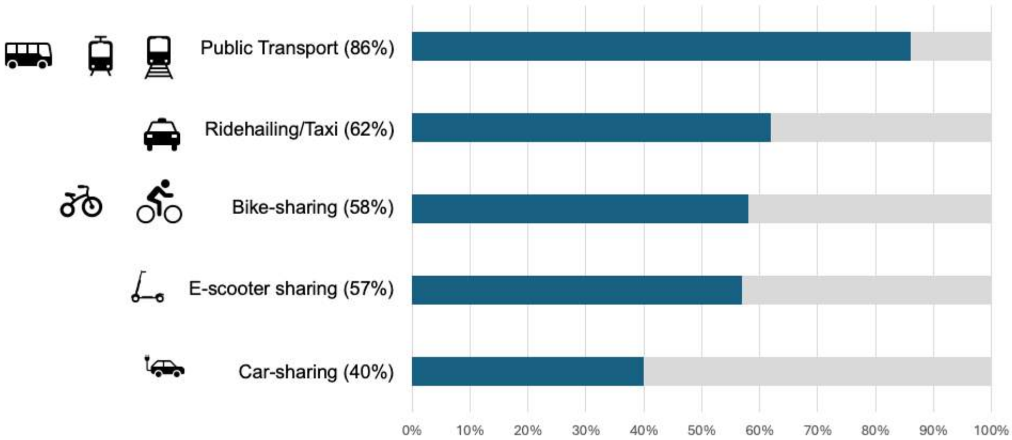
MaaS Services/ Resources	Lack of smartphone	Age > 65 years	Low Income	Physical disability	No Driver license	No driving skills	Digital illiteracy
Public transport	x						
Ride-hailing/Taxi	x		x				x

[4] A cell with an 'X' indicates that the specific transport mode (rows) might not be accessible if the criteria (columns) are unmet.

MaaS Services/ Resources	Lack of smartphone	Age > 65 years	Low Income	Physical disability	No Driver license	No driving skills	Digital illiteracy
Car-sharing / Motorcycle-sharing	x	x	x	x	x	x	x
Bike-sharing*	x	x		x		x	x
E-scooters	x	x	x	x			x

Following these levels, I measured the number of respondents with access to each type of service typically included in a MaaS bundle. The services range from the least to the most restrictive, as described by the exclusion conditions in Table 26). Figure 20 illustrates these percentages. It is important to note that multimodal MaaS systems rely on users accessing multiple modes per journey.

Figure 20. Respondents (%) with access to each service



In this empirical application, 40% of respondents had full access to MaaS, meaning they passed all exclusion conditions. These have all the necessary resources/capabilities to take advantage of the available shared modes. It is important to note that this approach may be unrealistic as many users do not require or want to use all indicated transport modes. I assumed that shared-mobility access levels are stacked over each other as a hierarchical system. Such hierarchical conditions make it difficult to tell which modes are accessible or not to individuals with distinct conditions.

8.3.4 Modeling Approach

The model aligns each respondent's resource availability with their reported use of shared mobility and new technologies. This allowed us to measure the impact of all considered resources on access to multiple modes typically included in MaaS bundles. I decided to compute and sum ***the number of modes each respondent could access*** (dependent variable) based on the classification and resource/ability associations indicated in Table 26. In other words, each resource works as an exclusion condition for each transport mode offered in MaaS bundles. The exclusion conditions (e.g., lack of smartphone, digital literacy, insufficient income, etc.) were encoded as binary variables, being “1” if the respondent met the condition (had the resource/ability) or “0” the other way. Each respondent’s access to different MaaS services/modes was interpreted as the dependent variable (number of services being able to use).

To analyze the influence of each resource on the access to MaaS, I estimated a generalized linear model (GLM) with a Binomial distribution. This specification was adopted because the dependent variable represents bounded count data (number of accessible modes out of a maximum total of six), making the binomial model appropriate and theoretically grounded. The binomial distribution accommodates the fact that the number of accessible modes cannot exceed six and allows us to model the probability of "success" (i.e., access to a number of modes) as a function of the available resources.

To model the number of transport modes accessible to each individual (ranging from 0 to 6), we employed a binomial generalized linear model (GLM) with a logit link function. In this framework, the number of accessible modes per respondent is considered a "success" in a sequence of six independent Bernoulli trials (for example “success” could be to have access to 2 modes and “failures” not having access to 4 modes). The model structure is:

$$Y_i \sim Binomial\ (n = 6, p_i)$$

where Y_i is the number of accessible modes for individual i, and p_i represents the underlying probability of being able to access a given number of modes. The logit link function relates this probability to a linear predictor:

$$\eta_i = \log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 X_{i1} + \ldots + \beta_k X_{ik},$$

where X_{ij} are the explanatory variables (e.g., individual resources or sociodemographic characteristics), and β_j are their estimated coefficients.

R statistical software and its built-in function “GLM” (Generalized Linear Model) was used to run the model.

8.4 Results

The model’s results show that not all the resources identified in the literature were critical, the dependent variable was defined as *“number of services able to use”* within a MaaS environment. All significant variables were included in the model. “Lack of smartphone” was left out because 98% of the respondents already owned one, leaving no room for heterogeneity. “Gender” (coded as Woman =1) was included despite not being statistically significant (p=0,09) given its theoretical relevance in MaaS and equity research. Moreover, its inclusion slightly improved model fit. Although the literature suggests women may face specific barriers to accessing MaaS (McIlroy, 2023), the data did not reveal statistically significant differences in access between genders.. The results are presented in “Digital literacy” showed the strongest effect on MaaS access (OR = 13.96, p < 0.001), followed by “possession of a driver’s license” (OR = 2.20, p < 0.001), “high income” (OR = 1.65, p < 0.001), “riding ability” (OR = 1.41, p < 0.001), and “data plan availability” (OR = 1.40, p < 0.001). In contrast, “Physical (Dis)ability” was associated with reduced odds of access (OR = 0.50, p < 0.001), indicating that individuals with self-reported physical disabilities are less likely to access multiple services. Gender (Woman) had a marginal, non-significant effect (OR = 1.10, p = 0.096).

Variables such as “spatial access,” “age,” and “foreign nationality” did not show statistically significant effects and were excluded from the final model.

To assess model fit, we report McFadden’s pseudo-R^2, which evaluates the improvement in model likelihood compared to an intercept-only (null) model. In the context of logistic and binomial models, values between 0.2 and 0.4 are typically interpreted as indicative of a model with good explanatory power (McFadden, 1974). In the model, the pseudo-R^2 is 0.562, suggesting a strong improvement over the null model. Additionally, the Likelihood Ratio test was highly significant ($\chi^2 = 5015.83$, df = 8, $p < 0.001$), indicating that the predictors jointly contribute meaningfully to the model. The lower AIC (3921.5) and BIC (3965) further support the adequacy of the model fit, when compared to alternative specifications (like Poisson or Quasi-Poisson) and the inclusion of other predictors. Finally, we verified that the dispersion parameter is close to 1 (dispersion = 1.03), indicating that the binomial model is well-calibrated in terms of residual variance and provides a suitable specification for the dependent variable. Together, these fit indices support the appropriateness of the chosen model structure.

Table 27.

“Digital literacy” showed the strongest effect on MaaS access (OR = 13.96, $p < 0.001$), followed by “possession of a driver’s license” (OR = 2.20, $p < 0.001$), “high income” (OR = 1.65, $p < 0.001$), “riding ability” (OR = 1.41, $p < 0.001$), and “data plan availability” (OR = 1.40, $p < 0.001$). In contrast, “Physical (Dis)ability” was associated with reduced odds of access (OR = 0.50, $p < 0.001$), indicating that individuals with self-reported physical disabilities are less likely to access multiple services. Gender (Woman) had a marginal, non-significant effect (OR = 1.10, $p = 0.096$). Variables such as “spatial access,” “age,” and “foreign nationality” did not show statistically significant effects and were excluded from the final model.

To assess model fit, we report McFadden’s pseudo-R^2, which evaluates the improvement in model likelihood compared to an intercept-only (null) model. In the context of logistic and binomial models, values between 0.2 and 0.4 are typically interpreted as indicative of a model with good explanatory power (McFadden, 1974). In the model, the pseudo-R^2 is 0.562, suggesting a strong improvement over the null model. Additionally, the Likelihood Ratio test was highly significant ($\chi^2 = 5015.83$, df = 8, $p < 0.001$), indicating that the predictors jointly contribute meaningfully to the model. The lower AIC (3921.5) and BIC (3965) further support the adequacy of the model fit, when compared to alternative specifications (like Poisson or Quasi-Poisson) and the inclusion of other predictors. Finally, we verified that the dispersion parameter is close to 1 (dispersion = 1.03), indicating that the binomial model is well-calibrated in terms of residual variance and provides a suitable specification for the dependent variable. Together, these fit indices support the appropriateness of the chosen model structure.

Table 27. Summary of GLM results and Incidence-rate ratios

Variable	**Estimate**	**Std. Error**	**z value**	**OR**	2.5%	97.5%
(Intercept)	-1.883	0.089	-21.069	0.152	0.128	0.181
Digital Literacy	2.636	0.063	41.530	13.96	12.33	15.82
Physical Disability	-0.699	0.112	-6.267	0.50	0.399	0.62
Riding ability	0.347	0.076	4.580	1.41	1.22	1.64
Data Plan availability	0.334	0.084	3.985	1.40	1.19	1.65
High Income	0.502	0.068	7.337	1.65	1.45	1.89
Gender (Woman)	0.095	0.057	1.663	1.10	0.98	1.23
Driver's License	0.787	0.057	13.730	2.20	1.96	2.46
AIC	3921					
BIC	3965					
Log. Ratio test	5016					
Pseudo R^2 (McFadden)	0.56					

For a more comprehensive interpretation of the results, we report odds ratios (ORs) for each variable, as presented in Table 27. Individuals with “Digital literacy” had nearly 14 times higher odds of accessing more MaaS services compared to those without this skill (holding all other factors constant). Followed by having a driver’s license with 2.2 times and being “high income” with 65% higher odds. Those with “Data plan availability” or “riding ability” had approximately 40% higher odds. In contrast, “Physical (dis)ability” reduced the odds of access by half, although the type of disability will indicate which specific services are excluded for the user; offering alternatives that require minimal user actions could still make MaaS an appealing option for these individuals.

In summary, “Digital literacy” stands out as the most critical resource/capacity required for MaaS access, followed by the availability of a “mobile data plan” and “riding ability”. This finding underscores the necessity of addressing digital inclusion and skill development to enhance the adoption of MaaS platforms. In contrast, the negative impact of “disability” on access suggests the need for more inclusive mobility services that consider individuals with physical limitations.

8.5 Discussion

This study contributes to the literature by breaking down MaaS into separate services and investigating resource-specific enablers and barriers to access. This detailed method not only closes the gap identified in the literature but also offers policymakers with practical insights. These findings challenge the assumption that access to MaaS means being able to use more than one mobility service, a common issue in MaaS bundle studies where pre-defined choice set scenarios are presenting without controlling if the individual can actually use all the modes being presented. The main conclusion is that we should not generalize access to MaaS, but the *degree of access* based on the number or which services can users use. This is a previous step that should be considered before assessing outcomes and preferences.

Moreover, as users may have different needs depending on the trip purpose, time of the day, day of the week, etc., the resources and capabilities they possess will determine which services will be included in their mobility package. On the other hand, public authorities and operators can use this information to mitigate those that become a barrier.

The results of the Generalized Linear Model (GLM) support the premise that MaaS services involve varying degrees of accessibility depending on the resources available to users. The main findings, directly derived from the model's result, are summarized in Table 28.

Table 28. List of findings

Finding	Description
Digital Literacy as a Key Factor	Digital literacy is crucial for MaaS access. Initiatives are needed to improve skills in vulnerable groups.
Economic Barriers and Transport Gentrification	High-income individuals enjoy better MaaS access. Policies must ensure affordable access for all users.
Role of Public Authorities	Public authorities must intervene to prevent MaaS from reinforcing socio-territorial inequalities, as well as prohibitive prices and selective operation areas.
Personalized MaaS Bundles	MaaS services should be tailored to individual needs to ensure wider accessibility.
Spatial Inequality in Service Availability	Shared mobility services are concentrated in wealthier areas, creating spatial exclusion. Service distribution must be equitable.

In Lisbon, the survey, in association with a literature review, identified the resources/capacities needed to use the different services included in a MaaS. Hence, personalized MaaS bundles are required if we want users to be able to use them fully. Since "Riding ability" emerged as a significant barrier to access. In our view, basic cycling skills should be taught at the elementary school level, as is already the casein some European countries. This, combined with the expansion of safe cycling infrastructure, could greatly reduce this barrier (Félix et al., 2020). In Lisbon, such measures are particularly feasible given the city's flat areas and the growing supply of public electric bikes (Gira) which effectively support mobility in hilly areas.

The results show that how new mobility services are supplied (and, therefore, adopted by the population) tends to benefit specific population segments. These services are commonly concentrated in wealthy or tourist places and only sometimes solve the low or middle-income population's travel needs. This could result from a market-driven approach in which for-profit operators may ignore urban mobility's societal goals, confirming Lucas' premise (2019) that "many companies will not currently rent cars to people living in social housing."

Following Lucas (2019), is relevant to assess if the current setting of shared mobility services could increase accessibility (optimists) or if, on the contrary, it increases the concentration of transport wealth amongst the already privileged and excludes marginalized groups (pessimists). The results show that if the public authority does not intervene in providing these services, the pessimistic scenario will become a reality in Lisbon, given that only 39% of potential users can use MaaS fully. The results on "Income" are essential for transport justice and indicate that stakeholders should regulate it to avoid possible transport gentrification.

Regarding other factors, "digital payment" was not considered in the analysis, given that it is no longer a barrier in the global North (if you have a smartphone, you can access this service). "Spatial access" was not directly associated with any service, given that the survey shows people who do not have it (people living in areas not served by shared mobility operators) still use it. The motivation behind this use is not clear. In the same tone, "Smartphone ownership" may not be a problem in Europe, but this may not be true for some global southern cities. From a policy perspective, and assuming that this factor may be an important barrier in certain situations, alternatives to smartphones, such as internet-enabled kiosks in public locations, train or bus stations, and free Wi-Fi in stations, stops, and dock locations, may mitigate the risk of exclusion.

I acknowledge some limitations to this study. The main limitation lies in the fact that, although the resources were derived from an extensive literature review, they represent a general framework that may not fully account for context-specific variations. Moreover, the defined dependent variable, "number of services able to use", was a self-defined construct based on exclusion assumptions. Therefore, the results are valid while the exclusion conditions of the resources identified hold true.

Another area for improvement is that some resources, more related to attitudes or preferences, could have been considered in this work, such as safety perception or tech savviness (Astroza et al., 2017; Hauslbauer et al., 2022; Orozco-Fontalvo et al., 2024a; Useche et al., 2023). Depending on the case, these could become barriers or motivators to use MaaS adoption at the individual level. Future research should examine whether the Resources identified in this study across cities with different levels of transport maturity and socio-economic contexts. Additionally, incorporating users' attitudes and exploring the effect of subjective resources (latent variables) through hybrid choice modelling could reveal further access barriers or enablers. Finally, given that no official MaaS platform operates in Lisbon, benchmarking against cities with established MaaS systems (e.g. Berlin, Vienna, Taipei) could provide meaningful insights into real-world access conditions. This comparative approach may also highlight additional variables not found in the literature such as language, race, or network awareness which remain unexplored in the literature

8.6 Conclusions

Based on a literature review, this study identified the resources needed to access MaaS It assessed how each impacts access to the services typically offered within a MaaS bundle through an empirical survey in Lisbon and a generalized linear model with a binomial distribution. The findings revealed that lacking specific resources can limit access to one or more services within a MaaS framework. In line with previous research, it was confirmed that elderly individuals and people with disabilities are at a higher risk of being excluded from some MaaS services. However, the analysis also highlighted that factors beyond sociodemographic characteristics can enable or hinder access. Being digital literacy the Resource with the highest IRR.

The main conclusion is that “access to MaaS” should not be treated as a binary condition. Instead, it depends on whether users can access each of the individual services included in a MaaS package. In this sense, we should think in terms of a “degree of access to MaaS” defined by the specific services users can actually use. Additionally, this study provides insights on the importance of each of the resources identified, allowing for a direct comparison or ranking among them.

Based on these insights, I recommend that public authorities play a role in deciding where to provide new mobility services and that operators consider the range of resources identified in this study to ensure broader access to the various modes of transport for a wider population segment. This layered, hierarchical structure of access levels suggests that MaaS solutions must consider each user’s individual limitations to avoid excluding large portions of the population. To guarantee that MaaS does not contribute to social exclusion, it is important to consider the necessary resources that potential users must possess to access the system. Future works should consider potential users' attitudes and confirm if there are subjective resources that may become a barrier or a motivator.

Finally, this work contributes to shared mobility research by highlighting the complex, resource-dependent character of MaaS access. This disaggregated study clearly demonstrates that enabling equal access to MaaS involves more than just increasing service availability; it also necessitates tailored measures that address the digital and material resources required for adoption. This study identified key areas where policy interventions can have a major impact, such as digital literacy and inclusive service design, using empirical evidence from the Lisbon case study. Additionally, the analysis not only addresses a key gap in the existing literature but also establishes a solid platform for future research on subjective and contextual barriers to MaaS, thus leading to better informed and successful transport justice initiatives.

Chapter 9: Mobility as a service (MaaS): Defining the role of public authorities

This work was partially presented at the HKSTS 2023 and is now under review as a journal article in the Research in Transportation Business & Management Journal.

Summary

I finish this dissertation by building on the findings and discussions from previous chapters, acknowledging that, if not properly implemented, MaaS risks leading to transport gentrification. As such public authorities should solve the access issues presented in Chapter 8, hence they should be at the heart of any MaaS system. The analysis presented throughout this work highlights the critical role of government intervention in preventing market failures and ensuring equitable mobility solutions. Based on this, this chapter close a research gap by proposing a tool to assess the extent of necessary public sector involvement in MaaS implementation. To operationalize this, classify the role of public authorities in 74 existing MaaS and "MaaS-like" systems worldwide, identifying key characteristics that shape their level of engagement. Based on these insights, I developed a flowchart designed to generalize and assist in defining the appropriate role of public transport authorities in MaaS implementation, applicable to any (democratic) authority.

9.1 Introduction

MaaS business model remains the main challenge towards its widespread adoption, with discussions on whether to choose a private-led, public-led or public-private MaaS; how to define the tariff levels and split between operators; how to handle data-sharing; among other topics. However, most of these discussions are aimed at ensuring the financial feasibility of the system, which I acknowledge it to be crucial, but usually ignoring the equity factor, which would be only considered if the public authority is involved in the process.

Nonetheless, the idea of a sovereign state dictating MaaS governance from a top-down approach is outdated and impractical, instead the focus should be in a pluricentric governance based on interdependence, negotiation and trust (Sørensen and Torfing, 2008, p. 3). In this framework, is still needed to define what would be the role of the public authority, for this, several schemes have been proposed, as the public authority been a regulator or a provider, or an integrator. However, based on the literature review conducted, there are no studies specifically explaining how to decide which role to play.

Moreover, the "one-size-fits-all" premise proposed by Hietanen (2014) may fall short if we consider the differences and specific characteristics among cities. For instance, London's institutional design has some limitations for mobility policy-making compared with Seattle (Moscholidou and Pangbourne, 2020). Some global south cities do not have the IT infrastructure or institutional design for a fully integrated MaaS (Hasselwander and Bigotte, 2022). Micromobility and data-sharing regulations are more advanced in certain cities/countries than in others. Public institutions' funding and capacity also vary (even more if we compare urban to rural areas). These and other barriers hinder the ability to design, operate, and regulate a "universal" MaaS system. In this framework, the role of public authorities in MaaS development and implementation should be addressed from a context-specific perspective, as in in any complex mobility system (Macário, 2011).

This decision involves considering the interaction and coordination of MaaS stakeholders, namely: MaaS Integrator: Aggregates services, manages the platform, and interfaces with users; Operators: Supplies the actual mobility services (e.g., public transit, bikeshare, rideshare); Public Authority (State): Sets policies, ensures fairness, and may fund or subsidize services (or not); Technology Enabler: Provides software, payment systems, or data infrastructure; And End-User (Traveler): The consumer whose needs ultimately shape MaaS design.

In this regard, state institutions are crucial in steering smart mobility towards international sustainability and urban development objectives. MaaS has the potential to become an effective tool to that end. If a MaaS system remains unregulated, it could also have negative effects, such as increased inequality or a shift away from conventional public transportation to (single occupancy) e-hailing, however, different dilemmas hinder the definition of the level of involvement or interventionism of the state: Oversteering vs**.** Understeering: Too much state control stifles innovation; too little risks inequity or market monopolies; Legitimacy: Who gets to decide the "rules of the game"? (e.g., Should a private operator have a say in MaaS standards?); Flexibility vs. Stability: MaaS requires adaptive governance but also predictable rules for investment. Hence, ***how to identify the most suitable role for a public authority in MaaS implementation?***

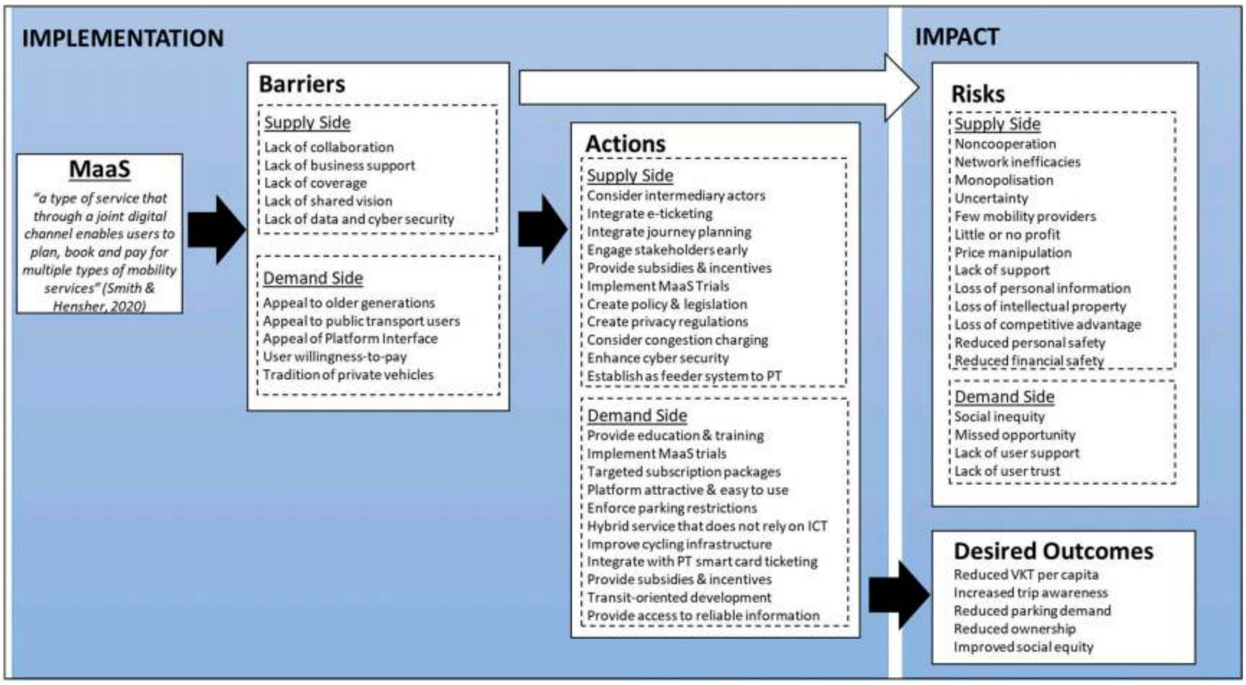
In this chapter, I aim to address this issue and propose a new method for identifying the most suitable role a public transport authority (PTA) should play in MaaS adoption based in multi-level perspective and metagovernance theory.

9.2 Literature review

MaaS systems led by private companies may generate undesirable “transport gentrification” and loss of institutional capacity (Pangbourne et al., 2020a). Furthermore, Docherty et al. (2018) argue that the state must intervene in MaaS systems, given that smart mobility may exacerbate long-standing transport problems, especially in urban areas, if the providers remain unregulated.

Butler (2021b) identified the main barriers to MaaS implementation, including a lack of collaboration (between stakeholders), a lack of shared vision, and lack of data (Figure 21). MaaS faces users' perspectives, policies, urban plan integration, business model, and competitiveness, among the main challenges (Li and Voege, 2017b). Non-cooperation, monopolization, price manipulation, and a lack of support are risks that governance could control. However, the emerging body of literature on MaaS offers limited guidance for policymakers (Smith and Hensher, 2020a).

Figure 21. MaaS barriers and risks



The literature regarding MaaS governance models divides them mainly in three categories: Market-driven approach, where private companies develop and operate; Public transport extension, where the PTA controls and provides the service; and a combination of both, which is basically a public-private partnership (Alyavina et al., 2022; Li, 2019; Narupiti, 2019; Smith et al., 2018a).

However, each model has its own strengths and weaknesses. In the market-driven approach, societal goals could be left aside if there is no strict regulation from the PTA, raising equity issues. On the other hand, public sector actors tend to reproduce institutionalized practices in resisting the development of innovation (Chesbrough, 2002; Geels, 2014), possibly hindering initiatives to improve the current system. In summary, the path to a MaaS will not be hampered by technological development but by governance issues (Arias-Molinares et al., 2022), I argue that the PTA should enable and play a role in MaaS implementation, which should be defined considering its context-specific characteristics.

The research on broader implications for MaaS governance is underdeveloped, and this gap has been repeatedly highlighted in recent publications (Audouin and Finger, 2018b; Butler et al., 2021a; Casadó et al., 2020; Pangbourne et al., 2020a; Singh, 2020; Smith and Hensher, 2020a). However, no studies in the literature propose a model that adequately integrates governance into the MaaS structure. Hence, to support decision-makers (and takers), MaaS governance needs to be appropriately addressed. If we consider the six ways of being defeated by Sun Tzu (2010) and apply them to a MaaS context, the six ways for a MaaS system to fail would be 1) Not assessing the demand, coverage, and modes to be included, 2) not having a clear incentives and penalties system (for both users and providers), 3) having unqualified personnel or lack of infrastructure, 4) having irrational passion towards its implementation, 5) having unclear regulations and no rule of law, and 6) not being fully integrated. All of which are mainly governance issues.

I refer to governance “as every mode of political steering involving public and private actors, including traditional modes of government and different types of steering, from hierarchical imposition to sheer information measures” (Windhoff-Héritier, 2002). It relates to how societies establish and preserve norms and order in social processes to pursue collective goals.

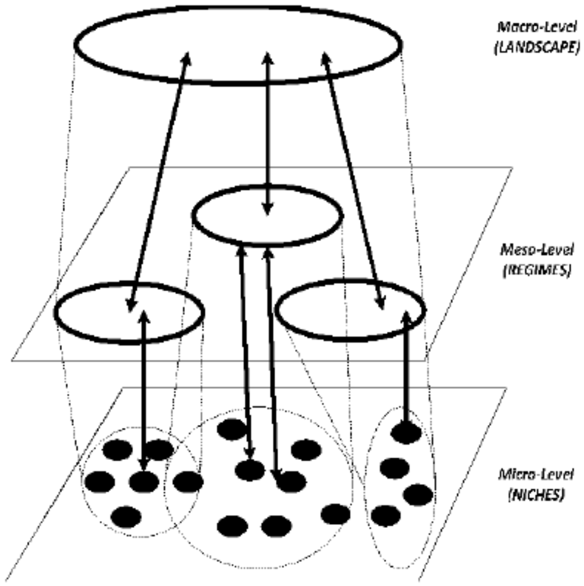
In this sense, Hirschhorn et al. (2019) analyzed how the public sector responded to MaaS to identify and conceptualize existing governance approaches to this innovation and classified the different approaches using multi-level perspective (MLP), considering the characteristics of the network, the institutional design and the MaaS stage the cities were currently on. and meta-governance in six roles (Analyzer, Architect, Lawmaker, Convener, Experimenter, and Provider) depending on the characteristics of the network, the institutional design and the MaaS stage the cities were currently on.

MLP is a widely used approach to address new technology adoption, diffusion, or rejection (Geels, 2002). However, MLP has the limitation of a lack of conceptualization of actors' roles and strategies in transitions. Hirschhorn et al. (2019) complemented this limitation with meta-governance theories (Sorensen and Torfing, 2005). The state of the art of this method (Geels, 2020) already relies on a synthesis of the social construction of technology, evolutionary economics, and neo-institutional theory, as applied by (Mladenović and Haavisto, 2021).

9.2.1 Multi-level perspective on socio-technical transitions (MLP)

MLP is a theory based on the premise that transitions are a product of interaction of three layers: Landscapes, Regimes and Niches (Geels, 2002). Landscapes refer to exogenous elements that are not directly influenced by regimes or niches, but have the power to put pressure on them and eventually modify it, some examples are demographics, preferences, public awareness, macro-economy, etc. Regimes refer to the rules or mainstream system that coordinates the activities of social groups, and are constituted by multiple dimensions such as technology, transport network and regulation. This means that a transition occurs when there is a regime shift. The niches are innovation and technological developments that are protected (i.e. R&D Labs) from the regime, that creates new ideas (i.e. MaaS) and usually struggle to overcome the regimes constraint for its implementation.

Figure 22. MLP diagram



Source: (Geels, 2002)

However, it has been criticized by several authors given it ignores actors roles, politics and possible omission of institutions and ideologies (Meadowcroft, 2011) which is why, as Hirschhorn (2019) did, I integrate meta-governance theories to overcome the MLP limitations. The characteristics considered for the decision tree and encompassed within the MLP perspective will be selected mainly from previous work who have already identified them as possible barriers (Butler et al., 2021a; Hasselwander and Bigotte, 2022), and complemented with my own research.

9.2.2 Meta-governance concept

"Governance networks" is a research field founded on the non-hierarchical forms of governance based on the interaction between public, semi-public and private actors. (Sørensen and Torfing, 2008, p. 3). Its rise is supported on the argument that policy (the attempt to achieve a desired outcome) is a result of the interaction of different stakeholders that is not necessarily fully controlled by the government. The main issue of this research field is to define to what extend should networks be regulated. As one the main pillars of it is self-regulation, however if governance networks remain unregulated it may affect societal goals. This generated a new form of governance and regulation called “Metagovernance” a regulated self-regulation.

It is described in the literature as a “as a practice by (mainly) public authorities that entails the coordination of one or more governance modes by using different instruments, methods, and strategies to overcome governance failures”(Gjaltema et al., 2020). It is an important concept given it allow us to analyze the relationship between public authority and governance networks, helping to guarantee accountability and transparency. One of its advantages is promoting collaborative governance by allowing the participation of a plurality of stakeholders in the decision-making, as it favors the democratic legitimacy of the public policy. This has made metagovernance to be recommended at local, national and transnational levels (EU, 2001).

There are four foundational theoretical perspectives on metagovernance, namely interdependency, governability, integration and governmentality theory. Interdependency theory claims that metagovernance can be done by whoever has the resources to do it and that it can help improve governance networks through conflict mediation, process planning and diplomacy, it encourages hands-on forms of metagovernance by combining network, state and market to reduce the degree of governing failures creating an imperfect way of governing society, this implies changing the view of public administrators as rule-following bureaucrats towards a creative, pragmatic and engaged facilitators (Jessop, 2002). While this theory considers state, market and networks as equally imperfect forms of governance with different strengths and weaknesses, governability theory places governance networks over state and market, presenting it as the most efficient way for efficient governance. However, due to its complexity and instability it can only be achieved by intensive metagovernance, it encourages hands-off metagovernance through institutional design by the construction of the “rules of the game”(Kooiman, 2010).

On the other hand, integration theorists encourage a metagovernance of identities (hands-off through norms, narratives, etc.) and capacities (hands-on through providing resources and learning opportunities). It suggests that metagovernance should cultivate shared meanings, norms and mutual respect among stakeholders. This includes how stakeholders perceive their roles and influence, promoting a political community (Scott, 2014). Lastly, the governmentality theory sees metagovernance as an invisible hand to regulate self-regulation. It focuses on empowering stakeholders as responsible and autonomous participants (subjectification) and embedding them into performance metrics, norms and benchmarks (subjection). This strategy allows power to be exercised at a distance: stakeholders feel free but operate under a defined framework, with the state playing a central, often indirect role in defining governance conditions (Burchell and Foucault, 2009).

All these theories insist that modern governance cannot be exercised through sovereign bureaucratic forms but must take the form of metagovernance. Moreover, although they present different approaches, these perspectives and forms are more supplementary one to another than exclusive, given both hands-on and hands-off interventions can work well together and that one approach may be efficient in a context but not in others.

Building on these, Sorensen & Torfing (2009) proposes four forms of metagovernance and define it as higher-order mode of governance that aims to coordinate and regulate the interplay between the state, market and networks. It involves framing and guiding (overarching rules, principles and norms); ensures coherences and synergy between stakeholders and public goals; manages interdependencies and conflicts and promote democratic legitimacy by ensuring accountability, transparency and inclusiveness. This said and considering the MaaS environment as a multi-stakeholder and high-complexity system, the metagovernance concept is suitable for the objective of defining the role of the public authority on its implementation.

9.2.3 MaaS Metagovernance

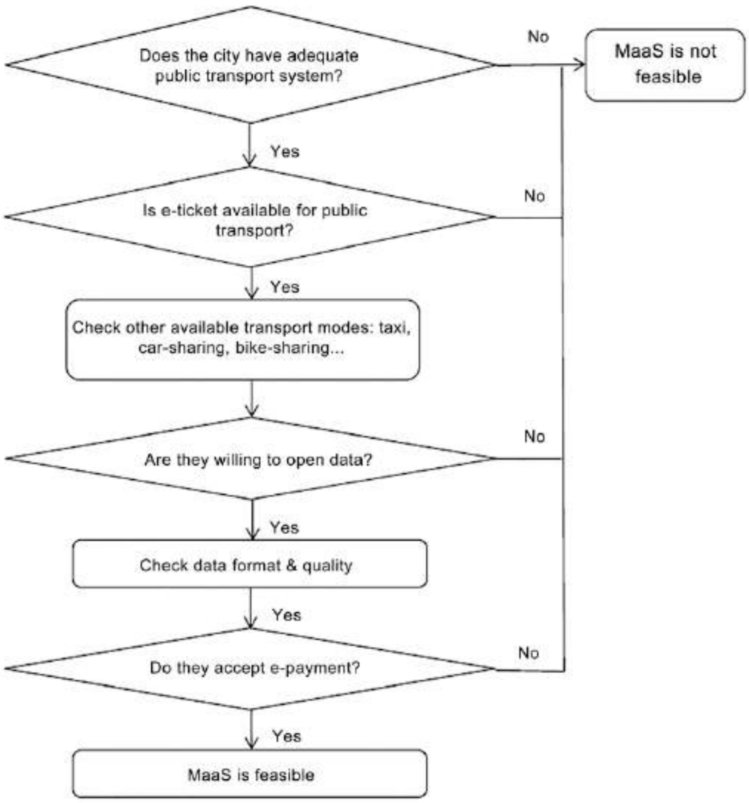
In this section I present an analysis of the applicability of the metagovernance theories to MaaS and select the most suitable to meet the objective. The interdependency theory pictures the state as a coordinator rather than a direct ruler, in a MaaS environment this means public authorities should define the regulatory framework and safeguard public interests. However, the strong emphasis on state influence may not be applicable in all MaaS contexts and may not fully capture the decentralized nature of MaaS ecosystems where many independent stakeholders must collaborate.

The governability theory recognizes the importance of involving different stakeholders, including private operators and tech companies, however it does not specify how to manage these interactions effectively. Regarding the integration theory can help explain how MaaS stakeholders align their interests, but it does not fully address the need for active coordination to create a seamless MaaS system. Lastly, the governmentality approach may be useful for understanding the sociopolitical dimensions of MaaS adoption but does not offer concrete mechanisms for structuring governance networks and managing stakeholders' interaction.

As none of the theories alone could address the role definition, I concur with the vision of a supplementary interaction between the theories and decided to use the metagovernance roles proposed by Hirschhorn et al (2019) specifically for MaaS which were based on Sorensen & Torfing (2009) to suggest the most suitable role for a public authority to address MaaS niches. The roles vary based on the PTA policy objectives, technical capacities, regional and national public transportation operations, institutional design and regulations. (Li, 2019).

However, neither Hirschhorn et al (2019) nor other authors provide a specific tool to replicate this or assign public authority roles comprehensively within a MaaS ecosystem. This may be due to the impossibility of the "one-fits-all" premise, for instance, The UITP limits to say "Depending on the local context, taking into account many factors such as the strength of established mobility services, the openness of the travelers, the institutional organization and legal framework for the transport services and many more, this role could be taken by different actors such as the public transport authority, any transport operator, a tech firm, a MaaS company or any other actor from the banking or the telecommunications sectors.". In this work, I intend to address this issue by proposing a tool to identify the most suitable role for a given public authority, this provides, first a starting point for any city to decide how to implement MaaS; second identify the level of readiness for a specific role; and third a tool for identifying opportunities on MaaS development.

Figure 23. Li & Voege (2017) check list



The closest decision tool available is the check list proposed by Li & Voege (2017b) (Figure 23) would be a first filter before attempting to define the role of the PTA; nevertheless it is too rigid, and basically says MaaS would be impossible in most global south cities. I argue that MaaS could be the push some cities need to innovate and modernize their system. For instance, an interested PTA could assume the role of an "experimenter", conducting pilots to test how it would work.

9.3 Methodology

To design the role definition tool of public transport authorities (PTAs) within a MaaS ecosystem, I used multi-level perspective as a conceptual framework. This approach helped structure the analysis of the socio-technical context the PTAs operate, guiding the identification of relevant variables or attributes that need to be considered to define the role (Table 29). A total of 7 steps were conducted as presented in Figure 24.

Figure 24. Methodological steps

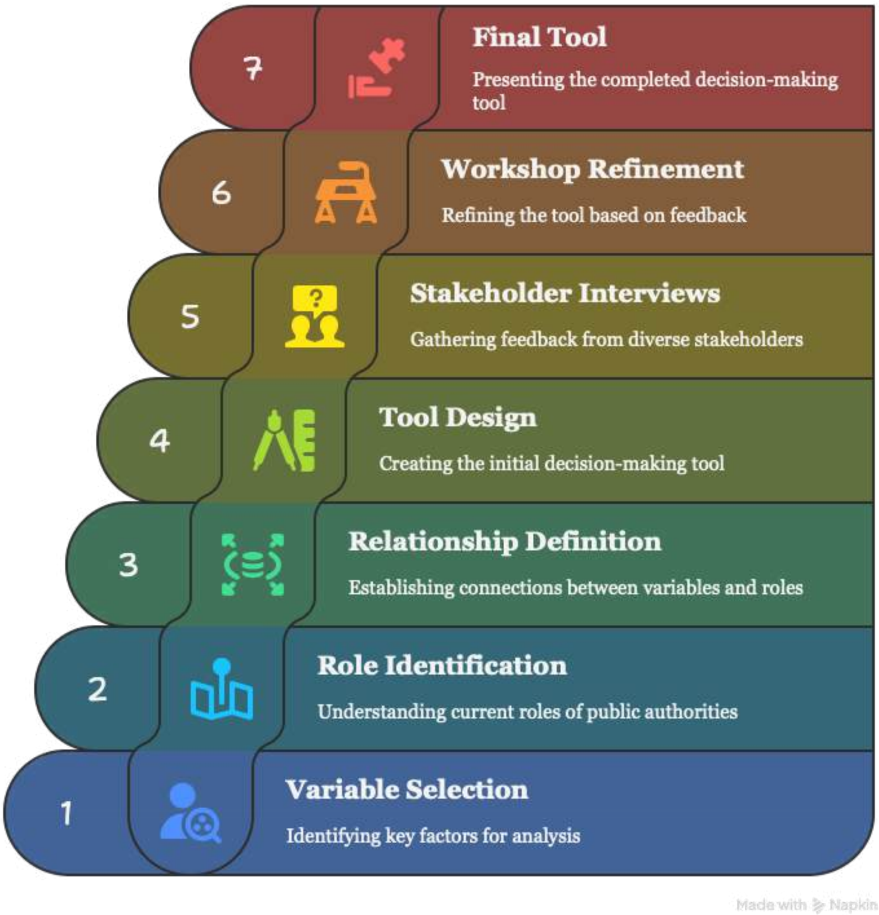


Table 29. Variables considered.

City's characteristics	Description	Levels
Public transport network IMPReSS classification	Refers to the quality and integration of the existing public transport using the IMPReSS classification method as a benchmark. (Chapter 4)	Low (< 20)/Medium (20-40) /High (>40)
Shared mobility services availability	Refers to the availability of more than two shared mobility services.	Yes / No
Electronic fare	Refers to whether there paperless ticketing validation.	Yes / No
Complex transitions experience	Indicates whether the Public Transport Authority (PTA) has previously managed complex institutional, technological, or operational transitions (e.g., large-scale reforms, new system integrations, digitalization). This serves as a proxy for the PTA's internal capacity and skill level of its human resources.	Yes / No

City's characteristics	Description	Levels
Institutional autonomy)	Refers to the autonomy and control the PTA has over the transport network and services, can it plan, implement and enforce policies or measures?	1. **Full authority** – to plan, regulate, and enforce policies across the transport network 2. **Shared/Partial authority** – it can influence policies but has limited enforcement or planning power. 3. **Limited authority** – minimal control; decisions are centralized or fragmented across other institutions.
Institutional engagement strategy	Refers to the interest of attitude of the PTA towards MaaS and how would they like to be involved on it.	• **Hands-on** – PTA intends to actively shape, coordinate, or lead MaaS efforts. • **Hands-off** – enabling private actors, offering data or regulatory support, but avoids direct operational roles. • **No action** – does not plan to engage in MaaS at this stage, either due to lack of interest, resources, or strategic alignment.

City's characteristics	Description	Levels
Regulatory control regime	Refers to the applicable regulatory framework for data-sharing and mobility services distribution.	• **Liberal** Open market with minimal barriers to entry, and data-sharing is required and accessible to all. Governance under light but clear rules. • **Open** Low regulation — private operators can enter freely, but there's little or no requirement for data-sharing or coordination with public authorities. • **Coordinated** Entry of private operators is permitted but requires compliance with specific conditions. require some level of data-sharing. Governance aims to balance innovation with public interest. • **Restricted** Tight regulatory control. Market access is highly

City's characteristics	Description	Levels
		regulated. Data is held centrally by authorities. (Audenhove et al., 2021)
Brand value	Refers to the current brand value that could be at risk if exposed to non-successful MaaS or that can be used to draw more users in a successful one.	High / Low-Indifferent (Arias-Molinares and García-Palomares, 2020a)
Funding (availability) for MaaS	Refers to the level of funding the PTA can obtain to implement MaaS or a MaaS pilot, disregarding if from public or private resources.	Yes / No
Private companies' interest	Refers to whether there are private companies interested in implementing a MaaS in the city	Yes / No-Indifferent

To link the identified variables to the roles I examined 74 operational MaaS or "partial-MaaS" systems across cities worldwide (from (Audenhove et al., 2021; Lopes et al., 2023) and my own research. Each case was coded using the previously defined variables classifying them according to the previously defined variables (Table 29) and the actual role assumed by the PTA (based on available documentation and contextual analysis). The roles (

Table 30) range from a minimal hands-off to a full hands-on approach, where the PTA acts as the MaaS provider, were drawn from Hirschhorn et al (2019).

By systematically comparing the variables categories on each case I identified recurring patterns and conditions associated with each PTA role. This was translated into a decision-support flowchart. To validate and refine the flowchart, I conducted several rounds of semi-structured interviews with different stakeholders (Operators, mobility consultants, academics and public authorities) from different urban landscape and regimes (Netherlands, Brazil, Colombia, Portugal and Spain). In each session the flow-chart was presented, assessed and discussed, leading to improved clarity, renaming variables, solving ambiguities and stablishing categories that matched real-life criteria. This iterative process led to several versions of the flow-chart until no further feedback was received/a consensus was reached/ all comments were addressed/ all comments were introduced.

Table 30. Proposed roles from Hirschhorn et al. (2019)

Role	Description	MLP	Sorensen & Torfing (2005)
Analyzer	Conducts scoping activities. Devolves responsibilities but seeks knowledge, collects evidence, and closely follows different initiatives to be equipped to intervene in a free market if deemed necessary.	Regime	-
Architect	Enables the niche with soft hands-off intervention to set broad goals framing policies and resources. Tasks are carried out by other network actors (contracted out) that have the freedom to act within policy and financial frames.	Regime	Policy and resource framing

Role	Description	MLP	Sorensen & Torfing (2005)
Lawmaker	Enables the niche with strong hands-off intervention. Regulation is the instrument to (re)design the system's institutional setup to allow market forces to drive innovation.	Regime	Institutional design
Convener	Enables the niche with soft hands-on intervention, using influence to help build relationships and networks. Supports and mediates dialogue and collaboration. Seeks mutually acceptable solutions. It relies on free market incentives for parties to develop solutions but ensures these are aligned with societal goals.	Regime and Niche	Facilitation
Experimenter	Enables the niche with strong hands-on intervention. The main aim is scoping via learning-by-doing. Seeks to maximize using living labs as 'controlled experiments'. Tasks are carried out by other network actors (contracted out), but outputs follow detailed guidelines.	Regime and Niche	-
Provider	Uses strong hands-on intervention. Mobilizes resources to design and offer desired solutions ascertaining a position of leadership, i.e., maintaining/recovering the original balance of power in a changing scenario.	Regime and Niche	Participation

We identified recurrent patterns and contextual conditions associated with each PTA role by comparing the variable configurations across all cases. These empirical regularities were synthesized into a decision-support flowchart designed to guide authorities in determining their optimal level of engagement in MaaS governance. To validate and refine this tool, we conducted five in-depth validation sessions, each lasting between 50 and 70 minutes, with experts representing key sectors of the MaaS ecosystem, including public transport authorities, private mobility operators, consultancy firms, and academia (refer to Table 31). Participants were drawn from the Netherlands, Colombia, Finland, Portugal, and Spain, representing diverse institutional environments and levels of MaaS maturity across both Global North and South contexts.

The preliminary flowchart was presented and discussed in an interactive format during each session. Participants were invited to assess the clarity of variables, the logical coherence of decision pathways, and the practical applicability of the tool to their own governance contexts. Feedback was documented, synthesized, and used to refine the framework through successive iterations, clarifying variable definitions, adjusting categorical thresholds, and simplifying decision routes to better reflect real-world governance dynamics. This expert co-design process continued until conceptual convergence was reached and no further substantive modifications were required, resulting in the final, consensus-based version of the decision-support tool.

Table 31. Profiles of experts interviewed for the stakeholder validation phase

Code	Position / Role (anonymized)	Type of Institution	Country / Region	Area of Expertise
INT1	Coordinator of shared mobility and innovation	Transport consultancy	The Netherlands	Shared mobility, innovation, MaaS implementation
INT2	Technical chief at a metropolitan mobility authority	Public authority	Colombia	Transport planning, public-sector management
INT3	Senior policy advisor and university professor	Consultancy / Academia (hybrid)	International (Portugal-based)	Governance, policy strategy, MaaS development
INT4	Former policy analyst at an international transport organization	International organization	Spain	Transport governance, public relations, policy analysis
INT5	Full professor of transport technology	Academia	Finland	Intelligent transport systems, innovation, research

In addition to the five expert interviews, a workshop was conducted with a group of researchers in transport and urban mobility. The session aimed to refine and validate the design and ensure the clarity and applicability of the proposed tool. Feedback from the workshop informed adjustments to the structure and terminology used in the final version.

9.4 The role definition tool

The resulting decision-support flowchart is presented in Figure 25. To use the tool, the process begins with applying the IMPReSS methodology to the transport system of the city under assessment, to determine the maturity level of its infrastructure and institutional arrangements. Next, users should follow the flowchart step by step, referring to Table 29 for detailed descriptions and guidance on evaluating each variable. Once the tool suggests a governance role, the PTA or any decision-maker applying the tool should judge whether the outcome aligns with their strategic objectives and contextual reality. If the resulting role diverges from expectations, users are encouraged to review the preceding variables to identify the underlying factors influencing the outcome. Addressing or strengthening these aspects may support a transition toward the desired role and inform future policy or capacity-building actions. A pre-requisite for using the tool would be data availability, if there is none, MaaS would not be feasible.

For an easier understanding, two examples are presented:

1) Transportes Metropolitanos de Lisboa (TML), Lisbon metropolitan transport authority (Figure 26): Classified as High IMPReSS, with complex transitions experience (Navegante card), with a high level of autonomy, mostly hands-on and not yet with a high brand value, resulting in a “Provider” role as a suggestion.

2) Area Metropolitana de Barranquilla, (AMB), Barranquilla’s transport authority (Figure 27): A low IMPReSS transport network, with hands-off approach, with complex transitions experience (BRT implementation), following results from

Chapter 5 I would expect private operators to be interested and the regulatory control regime would be coordinated, hence the tool suggest the role of “Lawmaker".

The tool in PNG format, as well as the 74 systems dataset, are available upon request to the author.

Figure 25. Decision support tool

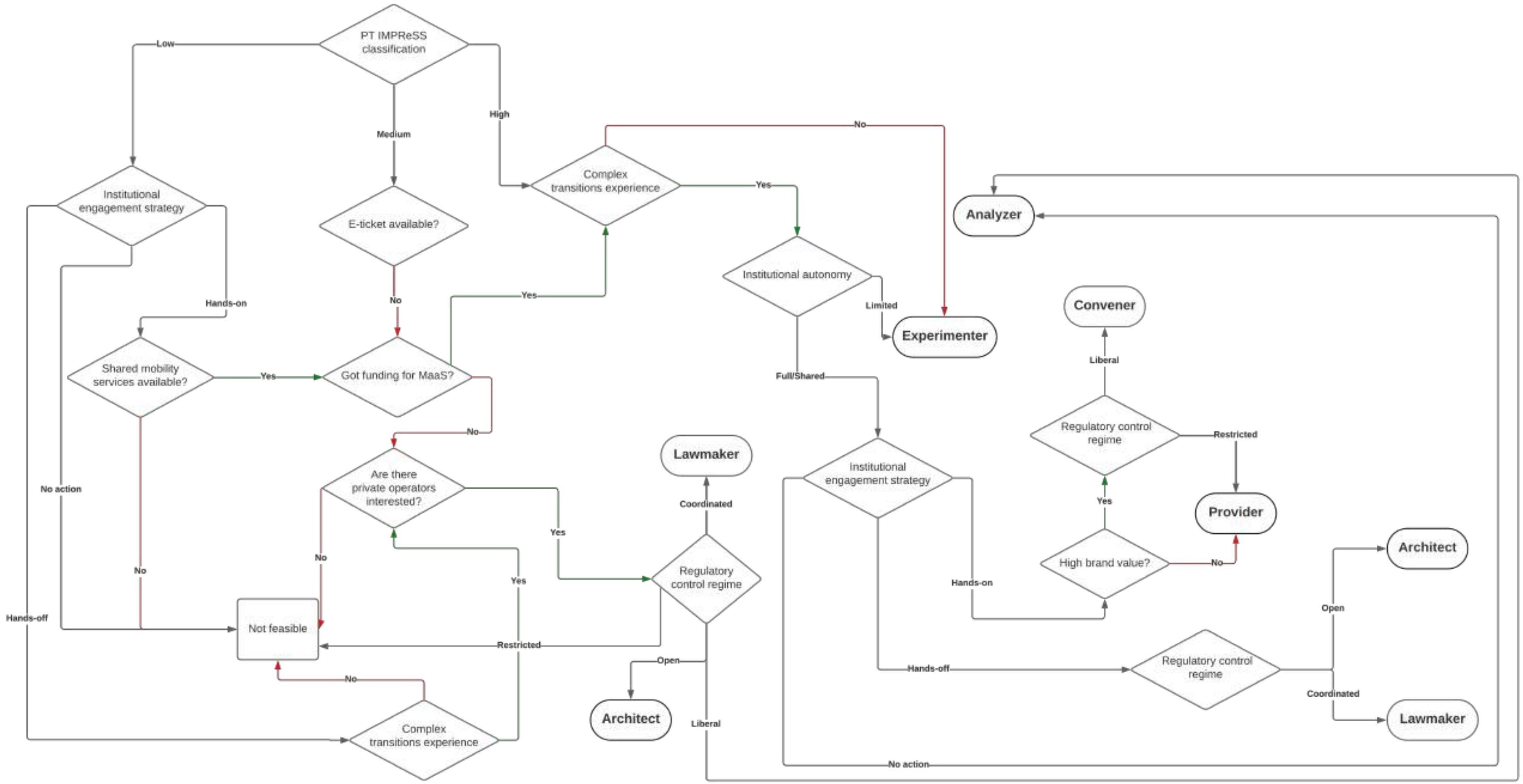


Figure 26. TML example

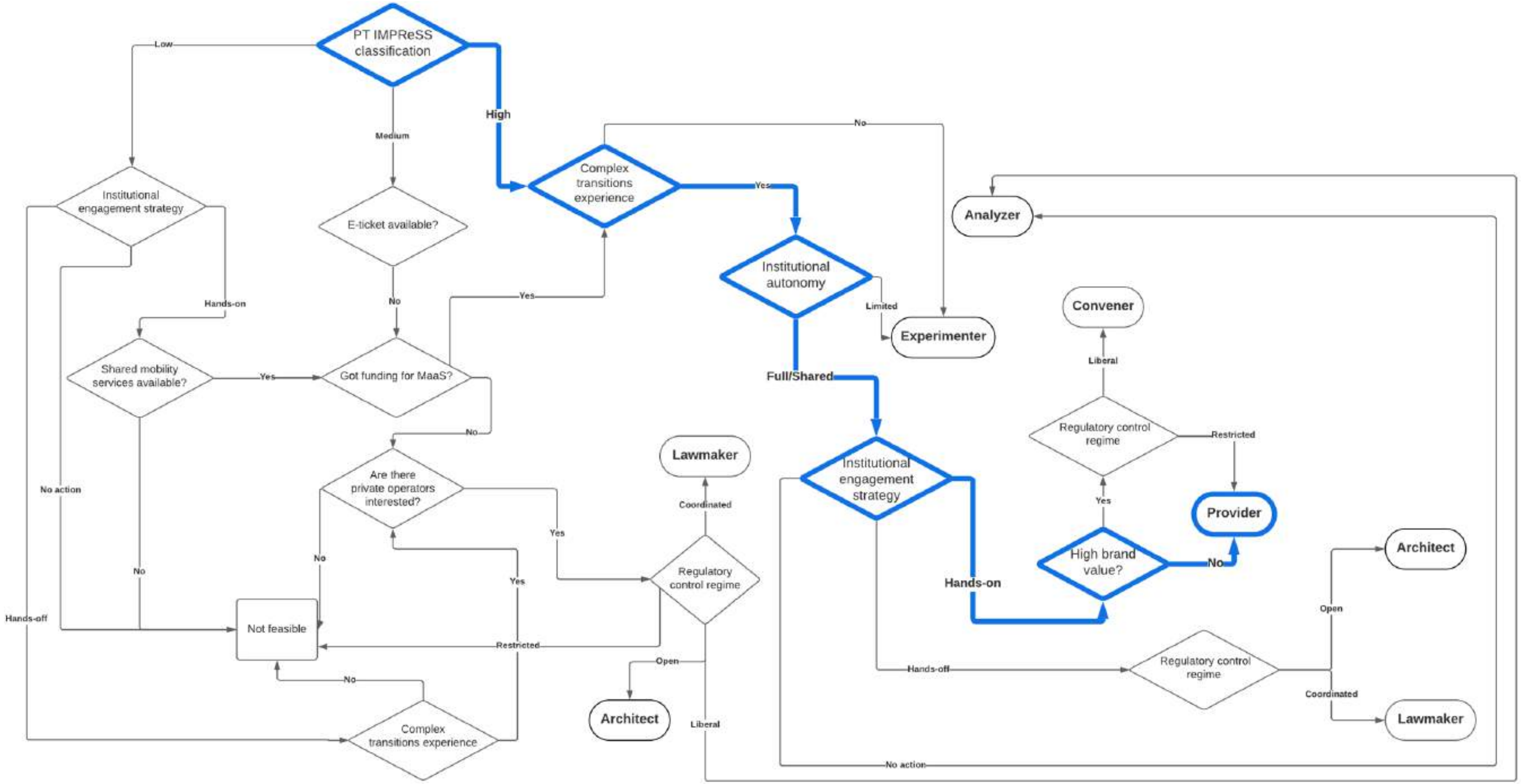
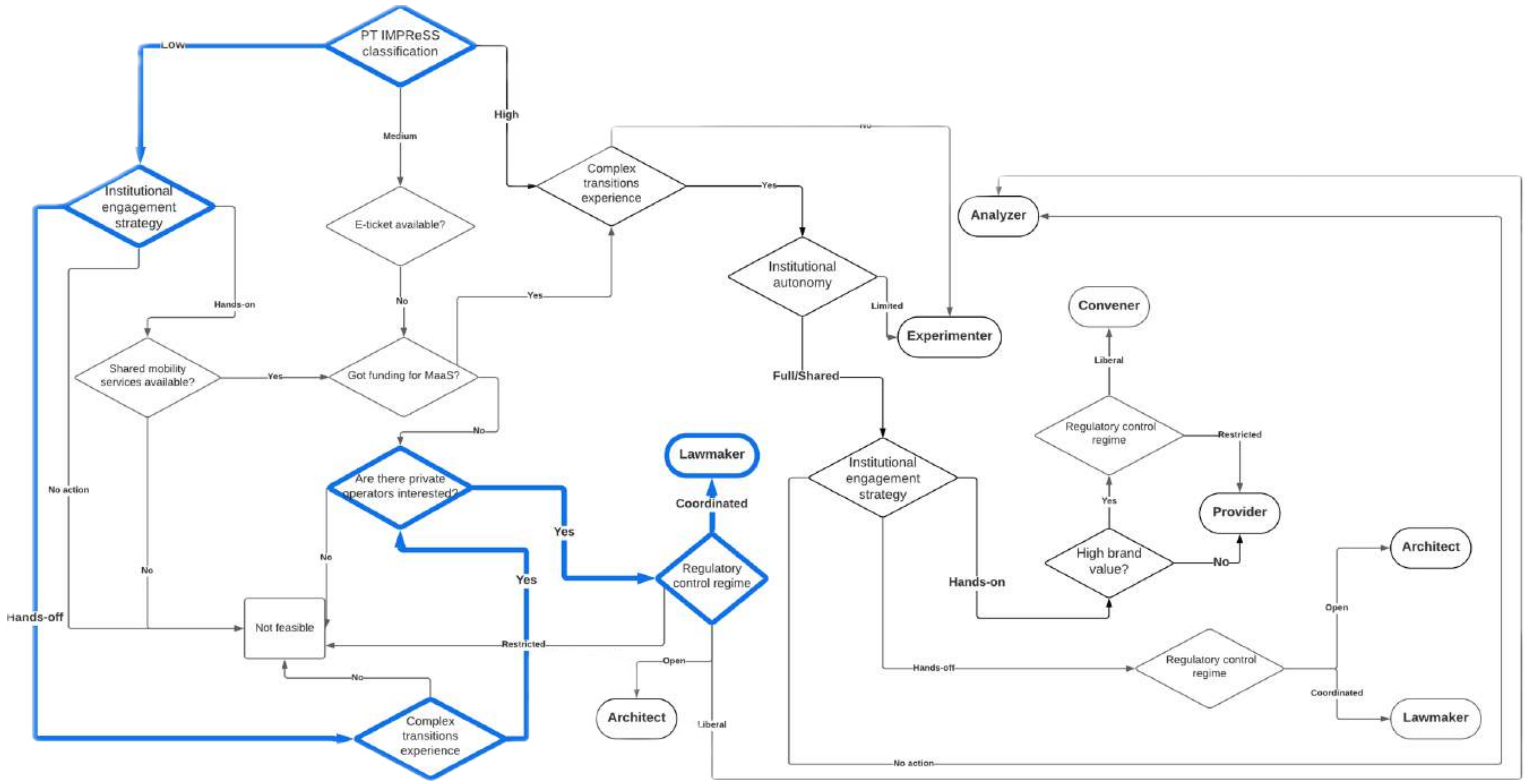


Figure 27. AMB example



9.5 Discussion

The decision-support flowchart confirms that identifying the most suitable role for a Public Transport Authority (PTA) in MaaS governance is inherently context-dependent. While some PTAs may express a high level of interest in adopting a hands-on approach, the tool reveals that this is not always strategically or operationally appropriate. Robust agencies—with well-developed infrastructure, institutional design, and high levels of IMPReSS (used here as a proxy for transport system maturity)—are best positioned to assume the “Provider” role. In contrast, PTAs with limited resources and lower levels of IMPReSS may find greater strategic value in roles such as Analyzers, Architects, or Experimenters. Importantly, not all variables influence each role equally. For example, “Experience with Complex Transitions” becomes critical only when a PTA seeks deeper engagement in MaaS operations.

These results aligns with previous work (Jittrapirom et al., 2017; Lajas and Macário, 2020; Smith et al., 2019), which highlights the importance of aligning MaaS governance strategies with local institutional and infrastructural capabilities. Moreover, by operationalizing the empirical patterns identified from existing MaaS systems into a structured flowchart, I provide a transparent and replicable tool that helps decision-makers avoid misaligned investment, minimize opportunity costs, and identify where to strategically focus their efforts while also highlighting opportunities for improvement. I argue that MaaS could become a reality in any city —varying the scale of its implementation— provided that the PTA role is appropriately defined and that this tool serves as a baseline mechanism for this definition.

The tool was iteratively refined during the validation stage, which allowed for clarification of the variables included and its levels and re-structuring the pathways for the role definition. However, some variables such as data-sharing (D’Agostino et al., 2019) and institutional autonomy (Li, 2019) may be challenging to define given the opacity of regulatory frameworks. These challenges may be mitigated in the coming years as regulatory landscapes become clearer and more supportive of integrated mobility governance.

This tool is a first step toward supporting PTAs in defining realistic and effective governance roles. It will undoubtedly benefit from further refinement as more successful implementations of MaaS are documented. The inclusion of key performance indicators (KPIs) could help the mitigate the possible subjectivity of the current version. However, the aim is not to over-quantify a system that is dynamic and context specific. Strict reliance on rigid metrics may fail to capture the diversity of local realities, potentially leading to inadequate conclusions. It may also neglect ethical considerations in standardization, which is of great importance in emerging technologies as this will impact the daily lives of commuters and their privacy (Gordon and Fomin, 2019).

A related concern is that structured tools such as this one it could unintentionally marginalize stakeholders whose needs fall outside the PTA planning, thus hindering the democratic legitimacy of transport-decision-making. Despite out effort to design an institutionally focused and internally consistent tool, multiple stakeholders may interpret it differently. Hence, although the proposed version prioritizes the PTA's perspective; a more inclusive, deliberative approach is necessary to be able to reconcile conflicting interpretations and support an adaptive role definition.

Beyond its academic contribution, the tool offers practical utility for transport decision-makers tasked with navigating MaaS implementation and provides an important opportunity to redefine public transport role to support sustainable mobility policies (Lajas and Macário, 2020). Public transport authorities, consultants, and MaaS operators can use the flowchart to assess governance readiness, prioritize investments, and define feasible implementation pathways. This is particularly relevant in procurement, partnership negotiation, and digital platform design, where misalignment between institutional capacity and strategic ambition often leads to implementation failure. It is also important to clarify that a the "provider" role, does not exclude private sector involvement. Rather, it denotes a high level of strategic and operational control, which may still involve outsourcing or contracting private operators for service delivery, software development, or integration tasks. This distinction helps avoid the common misconception that public leadership implies public exclusivity.

Regarding the limitations of this work, the use of publicly available online sources to determine systems characteristics and operational status (i.e., some systems listed as "operating" may in practice be inactive or permanently closed). This is particularly frequent in the MaaS ecosystem, where many start-ups and pilots fail to consolidate in the market. Another limitation lies in the empirical approach used to link the characteristics to the roles, which, while insightful and easy to understand and apply, is not exhaustive and may not seize the full range of variables and possible categories.

From a strategic standpoint, each governance role comes with its own operational implications that fall outside the current scope of the tool but merit further exploration. Once a role is identified, additional aspects and business model conditions should be defined, such as tariff structures, profit-sharing agreements, resale contracts, API integration, and data-sharing protocols, areas that should be further addressed in future work.

This said, this work contributes a novel, empirically grounded tool to the MaaS governance literature. It bridges empirical insights with multi-level perspective and meta-governance theories and offers a pragmatic foundation for PTA to define their roles in MaaS implementation.

9.6 Conclusions

As MaaS systems and other mobility innovations gain traction worldwide, PTAs face the challenge of fostering innovation and potential while guarantying the achievement societal goals and avoiding transport gentrification. If left to free market, MaaS could generate socio-territorial inequalities. I therefore argue that PTAs must take an active or enabling role in MaaS implementation and operation to ensure that the potential social benefits support the level of investment required.

In response to this challenge, I developed a decision-support tool that aligns PTA engagement strategies with their integration maturity, institutional capacity and regulatory contexts. Based on an empirical analysis of 74 global cases and using both Multi Level Perspective framework and meta-governance theories and refined by stakeholders' interviews, the flowchart provides a novel contribution to guide PTAs on how to address MaaS based on their context-specific characteristics.

I conclude that MLP and metagovernance proved to be a strong combination to help address governance issues in transportation, particularly in an era of constant niche creation and fast-paced innovation.

As stated in Chapter 3, "MaaS has the potential to improve urban transport significantly and to become an effective tool for public authorities to gain (or regain) control of the mobility network through the integration of several services". Given that it is a platform-based system, it can adapt, update, and include new services and innovations while dynamically providing reliable information and payment/booking systems for the users and steering it towards societal goals.

10. Thesis Conclusions

I would like to summarize my research by offering some final thoughts on a comprehensive investigation on MaaS, covering a wide scope and diversity of methods and contexts. I dealt with a diverse range of MaaS topics: a conceptual and classification proposal; a global overview on user perspectives (gathering data from 10 cities in different latitudes); expanding MaaS offering by going beyond traditional mobility services; suggesting case-wise bundles; and finalizing with addressing one of the main challenges in MaaS governance: The role of the public transport authorities. Additionally, in this chapter, I propose venues for future research and expose my own reflection on the matter.

Throughout the thesis, I provide a comprehensive perspective on how the MaaS ecosystem can evolve beyond its current limitations to become a viable, equitable, and useful mobility solution. I began by analyzing the equity implications of existing MaaS offerings based on the few real-world applications available at the time, which provided an overview of the challenges, caveats, and potential benefits of MaaS (Chapter 2). During the literature review, I identified a growing sense of disillusionment with the ability of MaaS to fulfill its promises. This skepticism may stem from a narrow perception of MaaS as merely a tool to reduce car ownership. It was at this point that I realized the need to take a broader perspective. As discussed in Chapter 3, the primary objective of MaaS should not be to reduce car ownership, but rather to deliver a well-integrated, seamless, and attractive transport service led by a public authority, where reduced car use is a consequence, not the goal. I arrived at this vision early in my research, which seemed bold given that it contrasted with the views of several established scholars. However, this perspective ultimately shaped the direction of my work. Now, after four years of continued research and discussing the topic in over six academic events, I am more convinced than ever that this approach should guide the development of any MaaS system.

All the following chapters were built upon this vision, and the results consistently support its validity. By approaching MaaS as presented in Chapter 3, it is possible to offer a more equitable service. This perspective allows for the design of context-specific offerings that reflect the different needs and different urban environments (or transport networks' maturity). It also enables MaaS to serve as a public management tool for improving the overall performance and development of the transport network, by advancing on the physical and digital integration of the services (Lajas and Macário, 2020). It can also add value by including non-personal mobility services such as parcel and food delivery, one of the main takeaways of my work, and an unintended result, as I didn't expect it to be highly preferred in all the cities studied. Furthermore, this broader view inspired me to design a decision framework to identify the diverse roles that public authorities can play in MaaS implementation and suggest the most suitable approach depending on institutional capacity, transport maturity, and resources. In this way, my thesis supports the notion that refocusing the MaaS approach can unlock its full potential.

10.1 Main research contributions

Highlighting the main contributions from this thesis, I would summarize them and reply to the research questions as follows:

To what extent do the current conceptualizations, approaches, and topologies of MaaS support an equitable transport system?

Current MaaS, conceptualizations, approaches, and topologies have several limitations that should be addressed in order to support an equitable system, specifically:

1. MaaS has the potential to enhance accessibility and address mobility gaps, but it may generate social and territorial inequalities and inequities (STIs) if poorly implemented. To ensure equity, inclusivity, and alignment with societal goals, public authorities must play an active role in governance. The ROOW framework helped identify exclusion risks, highlighting the need for context-specific, public-led MaaS strategies. In the absence of such supervision, MaaS could exacerbate rather than reduce STIs.

2. MaaS does not mean car-sharing nor privatization of transport. Moreover, it should not be judged solely by its ability to reduce car ownership. Instead, it must be valued for improving accessibility, enhancing sustainable mobility, and preventing car dependency among future generations. MaaS could be the tool public transport authorities need to steer urban mobility, becoming the cornerstone for strategic change.

3. The creation of IMPReSS, a novel tool for characterizing, assessing the potential, and comparing MaaS and MaaS-like systems, provides a practical framework to support decision-making, acknowledging the societal impacts of MaaS, overcoming the limitations of previous topologies that could also be used as a proxy for assessing transport network maturity.

What are the needs, preferences, and behaviors of users in relation to MaaS services and bundle configurations?

There is a high interest in MaaS, particularly in cities with immature transport networks. However, preferences significantly vary depending on the context, and as such, tailored mobility packages should be offered, including non-personal mobility services. Specifically:

4. My study on MaaS acceptance, conducted in 10 cities across four continents, revealed that the intention to use MaaS inversely relates to the maturity of the transport system (measured through IMPReSS). Local conditions significantly influence acceptance, and the factors that influence it vary among different levels of maturity, proving that a one-size-fits-all approach is inadequate. Contrary to the state of practice, this study also showed that the highest demand potential for MaaS is in Low IMPReSS cities, where users are generally more dissatisfied with their commute and would be more inclined to adopt it.

5. The services that should be offered in a MaaS bundle also need to be tailored to the preferences of users, which are also related to the IMPReSS level. After conducting a cluster analysis, I identified three different clusters for each IMPReSS level. These represent the

"typical" transport bundles that should be offered. Ride-hailing and home-delivery services were selected as complements to public transport in most of the clusters, with moto-taxi being highly preferred in one of the clusters of the Low IMPReSS cities. Car-sharing was not even in the top 5 of the services ranking, meaning it is not a priority for potential MaaS users.

6. MaaS could benefit from including non-personal mobility services such as Home Delivery Services (parcel and food). These services were highly preferred by our respondents and ranked higher than public transport in budget allocation. This could increase the added value of MaaS. For Lisbon, where Navegante already offers a multimodal and seamless public transport integration, a hypothetical partnership with home delivery services platforms could turn it into a SuperApp[5].

What regulatory roles and strategic actions should public authorities undertake to effectively govern and implement MaaS?

As a public management tool, MaaS should be led by public authorities in order to guarantee its access to different population groups and ensure it delivers an equitable service. To effectively governing MaaS public authorities should carefully define the role they will conduct during its implementation and operation. For this:

7. We must guarantee access to MaaS. Offering an affordable and inclusive service to avoid social exclusion, increase population digital literacy, and riding ability (of bicycles, for instance) is needed. Spatial access and infrastructure deployment are also important if we

[5] "An application that provides end users (customers, partners or employees) with a set of core features plus access to independently created miniapps. The superapp is built as a platform to deliver a miniapps ecosystem that users can choose from to activate for consistent and personalized app experiences." (Gartner, 2022)

want to integrate trips with new mobility services; otherwise, the latter will mostly be used as leisure modes.

8. I provide a decision-support tool for public transport authorities to identify the most suitable role they should play in MaaS implementation, given a set of characteristics. It also helps decision-makers to avoid misaligned investments and compromising resources and efforts, while also highlighting opportunities for improvement or leverage.

10.2 Final reflection

From this, the main conclusion of my research is that **public authorities are underestimating and not harnessing the potential of MaaS.** However, MaaS has yet to prove its real added value in practice, and the only way to do it is through proper implementation and experimentation. Contrary to other views, I believe MaaS is not "dead"; my findings support this statement and align with Campoamor (2025), who states, "MaaS matters now more than ever, and this is why. It is the simplification of transport: unified fare, a unique App, paperless validation, reliable real-time information, and in a landscape that is supporting innovation MaaS is the winner". Additionally, MaaS Scotland (2024) highlights that "a lack of clear leadership is the single biggest challenge to successful delivery of MaaS Scotland", which I would say is also the case in many cities, as explored and addressed in Chapter 9.

Moreover, my research supports, complements, and provides a solid foundation for the stepwise implementation presented in MaaS Scotland's Roadmap. However, as repeatedly stated throughout the document, MaaS needs to be context-specifically tailored; hence, not all the avenues apply to every city. Key avenues include:

- The expansion of MaaS to national or international platforms reduces barriers, supporting scalability and commercial viability.
- Establishing a highly skilled, multidisciplinary, and dedicated team with shared or full autonomy and resources for MaaS development and implementation.

- Modernizing transport infrastructure to meet the technical needs of a fully integrated network, with long-term funding support (Pilots are not enough!).

- Convincing operators to see the bigger picture. If not, all mobility options are integrated into a MaaS system, and the promise of seamless travel disappears. This is, for me, the biggest challenge for MaaS: persuading private operators to relinquish exclusivity and competition in favor of the users, although it might seem utopian.

- Developing a knowledge-sharing platform: A collaborative platform to share experiences can lead to a higher success rate.

- MaaS needs marketing, and users need to understand what they gain with its usage. Shaping MaaS offerings, prioritizing the needs of the user, should be a priority. Regulations need to be altered to allow incentives, resales, and non-transport services to be offered. Although I support public-led MaaS, it should be treated as a living product, not a common public service. Metagovernance could shed light on this challenge.

Delving into this last point, applying neuromarketing principles to MaaS design could prove useful in increasing user adoption. First, the “Framing effect”, the way MaaS is presented and advertised, should be carefully defined, as it changes the way people may perceive it. Second, the “IKEA effect” suggests that people value things more if they feel they have contributed to their creation. Collaborative and communication channels that provide a sense of community should be explored. Third, the “Contrast” effect, people perceive something as better valued when placed next to a more expensive alternative. Advertising MaaS, highlighting its value alongside the benefits of using the car or non-integrated services, could influence adoption. Fourth, “The paradox of choice” offering too many options can overwhelm the user and create doubt, which is why it is important to consider the results of Chapter 6 about bundle design of mobility services.

Finally, I believe that MaaS should evolve to include not only non-personal mobility services but also non-mobility services too, such as gym membership, partnerships with stores located near

MaaS hubs, and other services that indirectly generate or attract trips, something I would call MOD or "MaaS Oriented Development". It also must include a reward program that goes beyond discounts, similar to the frequent flyer programs airlines use or loyalty cards of supermarkets, but how it would work, regulation implications, which incentives to offer, and doing it without overcomplicating the main objective of MaaS, should be further explored and developed in a future PhD.

References

Abdelwahab, B., Palm, M., Shalaby, A., Farber, S., 2021. Evaluating the equity implications of ridehailing through a multi-modal accessibility framework. Journal of Transport Geography 95, 103147. https://doi.org/10.1016/j.jtrangeo.2021.103147

Abouee-Mehrizi, H., Baron, O., Berman, O., Chen, D., 2021. Adoption of Electric Vehicles in Car Sharing Market. Production and Operations Management 30, 190–209. https://doi.org/10.1111/poms.13262

Abouelela, M., Al Haddad, C., Antoniou, C., 2024. Psychological factors impacts on carsharing use. Transportation. https://doi.org/10.1007/s11116-024-10514-4

Ahmed, W., 2025. Optimizing sustainable urban mobility through digital integration. Sustainable Futures 10, 100879. https://doi.org/10.1016/j.sftr.2025.100879

Al Haddad, C., Chaniotakis, E., Straubinger, A., Plötner, K., Antoniou, C., 2020. Factors affecting the adoption and use of urban air mobility. Transportation Research Part A: Policy and Practice 132, 696–712. https://doi.org/10.1016/j.tra.2019.12.020

Alfaro, E., Llamazares, F.J., Useche, S.A., 2024. What makes female commuters ‘unhappy’? Harassment, fear of crime, and unsought travel behavioral adaptations in public transport against life satisfaction. Journal of Transport & Health 37, 101835. https://doi.org/10.1016/j.jth.2024.101835

Alonso-González, M.J., Hoogendoorn-Lanser, S., Van Oort, N., Cats, O., Hoogendoorn, S., 2020. Drivers and barriers in adopting Mobility as a Service (MaaS) – A latent class cluster analysis of attitudes. Transportation Research Part A: Policy and Practice 132, 378–401. https://doi.org/10.1016/j.tra.2019.11.022

Alyavina, E., Nikitas, A., Njoya, E.T., 2022. Mobility as a service (MaaS): A thematic map of challenges and opportunities. Research in Transportation Business & Management 43, 100783. https://doi.org/10.1016/j.rtbm.2022.100783

Apouey, B., Roulet, A., Solal, I., Stabile, M., 2020. Gig Workers during the COVID-19 Crisis in France: Financial Precarity and Mental Well-Being. J Urban Health 97, 776–795. https://doi.org/10.1007/s11524-020-00480-4

Arias-Molinares, D., Carlos García-Palomares, J., 2020. Shared mobility development as key for prompting mobility as a service (MaaS) in urban areas: The case of Madrid. Case Studies on Transport Policy 8, 846–859. https://doi.org/10.1016/j.cstp.2020.05.017

Arias-Molinares, D., García-Palomares, J.C., 2020a. The Ws of MaaS: Understanding mobility as a service fromaliterature review. IATSS Research 44, 253–263. https://doi.org/10.1016/j.iatssr.2020.02.001

Arias-Molinares, D., García-Palomares, J.C., 2020b. The Ws of MaaS: Understanding mobility as a service fromaliterature review. IATSS Research 44, 253–263. https://doi.org/10.1016/j.iatssr.2020.02.001

Arias-Molinares, D., García-Palomares, J.C., Gutiérrez, J., 2022. On the path to mobility as a service: a MaaS-checklist for assessing existing MaaS-like schemes. Transportation Letters 1–10. https://doi.org/10.1080/19427867.2022.2038987

Astroza, S., Garikapati, V.M., Bhat, C.R., Pendyala, R.M., Lavieri, P.S., Dias, F.F., 2017. Analysis of the Impact of Technology Use on Multimodality and Activity Travel Characteristics. Transportation Research Record: Journal of the Transportation Research Board 2666, 19–28. https://doi.org/10.3141/2666-03

Audenhove, F.-J.V., Arby, H., Rominger, G., Tauvel, M., 2021. How to realize the promise of Mobility-as-a-Service. Arthur D Little: Future of Mobility Lab.

Audouin, M., Finger, M., 2018a. The development of Mobility-as-a-Service in the Helsinki metropolitan area: A multi-level governance analysis. Research in Transportation Business & Management 27, 24–35. https://doi.org/10.1016/j.rtbm.2018.09.001

Audouin, M., Finger, M., 2018b. The development of Mobility-as-a-Service in the Helsinki metropolitan area: A multi-level governance analysis. Research in Transportation Business and Management 27, 24–35. https://doi.org/10.1016/j.rtbm.2018.09.001

Balarezo, M.L.G., Trépanier, M., Jalbert, J., Boisjoly, G., 2024. Going the distance: Gender differences in travel in Montréal, Canada. Journal of Transport Geography 118, 103935. https://doi.org/10.1016/j.jtrangeo.2024.103935

Bandeira, J.M., Macedo, E., Teixeira, J., Cicarelli, G., Niculescu, M., Fischer, N., Gather, M., 2022. Multidimensional Indicator of MaaS systems Performance. Transportation Research Procedia 62, 491–500. https://doi.org/10.1016/j.trpro.2022.02.061

Banister, D., 2018. Inequality in transport. Alexandrine Press, Marcham.

Barbour, N., Zhang, Y., Mannering, F., 2020. An exploratory analysis of the role of socio-demographic and health-related factors in ridesourcing behavior. Journal of Transport & Health 16, 100832. https://doi.org/10.1016/j.jth.2020.100832

Bauchinger, L., Reichenberger, A., Goodwin-Hawkins, B., Kobal, J., Hrabar, M., Oedl-Wieser, T., 2021. Developing Sustainable and Flexible Rural–Urban Connectivity through Complementary Mobility Services. Sustainability 13, 1280. https://doi.org/10.3390/su13031280

Bezai, N.E., Medjdoub, B., Al-Habaibeh, A., Chalal, M.L., Fadli, F., 2021. Future cities and autonomous vehicles: analysis of the barriers to full adoption. Energy and Built Environment 2, 65–81. https://doi.org/10.1016/j.enbenv.2020.05.002

Bichsel, R., Weiß, S., 2021. Sustainable mobility: Will MaaS replace private car use? Intelligent Transport.

Böcker, L., Anderson, E., Uteng, T.P., Throndsen, T., 2020. Bike sharing use in conjunction to public transport: Exploring spatiotemporal, age and gender dimensions in Oslo, Norway. Transportation Research Part A: Policy and Practice 138, 389–401. https://doi.org/10.1016/j.tra.2020.06.009

Burchell, G., Foucault, M. (Eds.), 2009. The Foucault effect: studies in governmentality ; with two lectures by and an interview with Michel Foucault, Nachdr. ed. Univ. of Chicago Press, Chicago, Ill.

Butler, L., Yigitcanlar, T., Paz, A., 2021a. Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities: A systematic review of the literature. Cities 109, 103036. https://doi.org/10.1016/j.cities.2020.103036

Butler, L., Yigitcanlar, T., Paz, A., 2021b. Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities: A systematic review of the literature. Cities 109, 103036. https://doi.org/10.1016/j.cities.2020.103036

Butler, L., Yigitcanlar, T., Paz, A., 2021c. Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities: A systematic review of the literature. Cities 109, 103036. https://doi.org/10.1016/j.cities.2020.103036

Butler, L., Yigitcanlar, T., Paz, A., 2020. Smart Urban Mobility Innovations: A Comprehensive Review and Evaluation. IEEE Access 8, 196034–196049. https://doi.org/10.1109/ACCESS.2020.3034596

Caballini, C., Corazza, M.V., Costa, V., Delponte, I., Olivari, E., 2022. Assessing the Feasibility of MaaS: A Contribution from Three Italian Case Studies. Sustainability 14, 16743. https://doi.org/10.3390/su142416743

Campoamor, G., 2025. The MaaS Opportunity: Strategic Insights from Scotland's Implementation Plan. URL https://www.linkedin.com/pulse/maas-opportunity-strategic-insights-from-scotlands-plan-campoamor-4fgpe/?trackingId=Jz10d2vLjdKBREJuaeOe6g%3D%3D

Casadó, R.G., Golightly, D., Laing, K., Palacin, R., Todd, L., 2020. Children, Young people and Mobility as a Service: Opportunities and barriers for future mobility. Transportation Research Interdisciplinary Perspectives 4. https://doi.org/10.1016/j.trip.2020.100107

Casas, I., 2007. Social Exclusion and the Disabled: An Accessibility Approach∗. The Professional Geographer 59, 463–477. https://doi.org/10.1111/j.1467-9272.2007.00635.x

Cervero, R., Golub, A., 2007. Informal transport: A global perspective. Transport Policy 14, 445–457. https://doi.org/10.1016/j.tranpol.2007.04.011

Chang, S.K.J., Chen, H.-Y., Chen, H.-C., 2019. Mobility as a service policy planning, deployments and trials in Taiwan. IATSS Research 43, 210–218. https://doi.org/10.1016/j.iatssr.2019.11.007

Chesbrough, H., 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Industrial and Corporate Change 11, 529–555. https://doi.org/10.1093/icc/11.3.529

Chinaei, M.H., Hossein Rashidi, T., Waller, T., 2022. Digitally transferable ownership of mobility-as-a-service systems using blockchain and smart contracts. Transportation Letters 1–8. https://doi.org/10.1080/19427867.2021.2018556

Christensen, T.H., Friis, F., Nielsen, M.V., 2022. Shifting from ownership to access and the future for MaaS: Insights from car sharing practices in Copenhagen. Case Studies on Transport Policy 10, 841–850. https://doi.org/10.1016/j.cstp.2022.02.011

Chung, Y., Choi, K., Park, J., Litman, T., 2014. Social exclusion and transportation services: A case study of unskilled migrant workers in South Korea. Habitat International 44, 482–490. https://doi.org/10.1016/j.habitatint.2014.09.005

Church, A., Frost, M., Sullivan, K., 2000. Transport and social exclusion in London. Transport Policy 7, 195–205. https://doi.org/10.1016/S0967-070X(00)00024-X

Clark, A.V., Atkinson-Palombo, C., Garrick, N.W., 2019. The Rise and Fall of the Segway. Transfers 9, 27–44. https://doi.org/10.3167/TRANS.2019.090203

Cuofano, G., 2024. The Buy-a-Feature Prioritization Model. URL https://fourweekmba.com/buy-a-feature-prioritization-model/

Curtale, R., Liao, F., Van Der Waerden, P., 2021. User acceptance of electric car-sharing services: The case of the Netherlands. Transportation Research Part A: Policy and Practice 149, 266–282. https://doi.org/10.1016/j.tra.2021.05.006

Dadashzadeh, N., Woods, L., Ouelhadj, D., Thomopoulos, N., Kamargianni, M., Antoniou, C., 2022. Mobility as a Service Inclusion Index (MaaSINI): Evaluation of inclusivity in MaaS systems and policy recommendations. Transport Policy 127, 191–202. https://doi.org/10.1016/j.tranpol.2022.09.006

Dados, N., Connell, R., 2012. The Global South. Contexts 11, 12–13. https://doi.org/10.1177/1536504212436479

D'Agostino, M., Pellaton, P., Brown, A., 2019. Mobility Data Sharing: Challenges and Policy Recommendations. UC Davis: Institute of Transportation Studies.

De Vos, J., Witlox, F., 2013. Transportation policy as spatial planning tool; reducing urban sprawl by increasing travel costs and clustering infrastructure and public transportation. Journal of Transport Geography 33, 117–125. https://doi.org/10.1016/j.jtrangeo.2013.09.014

Deboosere, R., El-Geneidy, A.M., Levinson, D., 2018. Accessibility-oriented development. Journal of Transport Geography 70, 11–20. https://doi.org/10.1016/j.jtrangeo.2018.05.015

Di Ciommo, F., Shiftan, Y., 2017. Transport equity analysis. Transport Reviews 37, 139–151. https://doi.org/10.1080/01441647.2017.1278647

Ding, C., Cao, X., 2019. How does the built environment at residential and work locations affect car ownership? An application of cross-classified multilevel model. Journal of Transport Geography 75, 37–45. https://doi.org/10.1016/j.jtrangeo.2019.01.012

Docherty, I., Marsden, G., Anable, J., 2018. The governance of smart mobility. Transportation Research Part A: Policy and Practice 115, 114–125. https://doi.org/10.1016/j.tra.2017.09.012

Dowling, R., 2018. Smart Mobility: Disrupting Transport Governance?, in: Governance of the Smart Mobility Transition. Emerald Publishing Limited, pp. 51–64. https://doi.org/10.1108/978-1-78754-317-120181004

Durand, A., Kennisinstituut voor Mobiliteitsbeleid, Ministerie van Infrastructuur en Milieu, 2018. Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review. KiM|Netherlands Institute for Transport Policy Analysis, The Hague.

Durand, A., Zijlstra, T., Hamersma, M., Hoogendoorn-Lanser, S., Hoogendoorn, S., 2023. “Who can I ask for help?”: Mechanisms behind digital inequality in public transport.

Durand, A., Zijlstra, T., van Oort, N., Hoogendoorn-Lanser, S., Hoogendoorn, S., 2022. Access denied? Digital inequality in transport services. Transport Reviews 42, 32–57. https://doi.org/10.1080/01441647.2021.1923584

Dzisi, E., Obeng, D.A., Tuffour, Y.A., Ackaah, W., 2023. Digitalization of the paratransit (trotro) using mobility as a service: What are the adoption intentions of operators and operator unions in Ghana? Research in Transportation Business & Management 47, 100968. https://doi.org/10.1016/j.rtbm.2023.100968

Eckhardt, J., Lauhkonen, A., Aapaoja, A., 2020. Impact assessment of rural PPP MaaS pilots. Eur. Transp. Res. Rev. 12, 49. https://doi.org/10.1186/s12544-020-00443-5

Esztergár-Kiss, D., Kerényi, T., 2020. Creation of mobility packages based on the MaaS concept. Travel Behaviour and Society 21, 307–317. https://doi.org/10.1016/j.tbs.2019.05.007

Esztergár-Kiss, D., Kerényi, T., Mátrai, T., Aba, A., 2020. Exploring the MaaS market with systematic analysis. Eur. Transp. Res. Rev. 12, 67. https://doi.org/10.1186/s12544-020-00465-z

EU, 2001. European Governance: A White Paper (Brussels, The Commission of the European Communities).

European Commission, 2022. Study on new mobility patterns in European cities: final report. Task A, EU wide passenger mobility survey. Publications Office, LU.

European Union, 2023. Digital literacy in the EU: An overview.

Faqih, K.M.S., 2016. An empirical analysis of factors predicting the behavioral intention to adopt Internet shopping technology among non-shoppers in a developing country context: Does gender matter? Journal of Retailing and Consumer Services 30, 140–164. https://doi.org/10.1016/j.jretconser.2016.01.016

Fedorowicz, M., Bramhall, Emily, Treskin, Mark, Ezike, Richard, 2020. New mobility and equity: Insights for medium-size cities. Urban Institute, Washington, DC.

Félix, R., Cambra, P., Moura, F., 2020. Build it and give 'em bikes, and they will come: The effects of cycling infrastructure and bike-sharing system in Lisbon. Case Studies on Transport Policy 8, 672–682. https://doi.org/10.1016/j.cstp.2020.03.002

Félix, R., Orozco-Fontalvo, M., Moura, F., 2023. Socio-economic assessment of shared e-scooters: do the benefits overcome the externalities? Transportation Research Part D: Transport and Environment 118, 103714. https://doi.org/10.1016/j.trd.2023.103714

Fioreze, T., De Gruijter, M., Geurs, K., 2019. On the likelihood of using Mobility-as-a-Service: A case study on innovative mobility services among residents in the Netherlands. Case Studies on Transport Policy 7, 790–801. https://doi.org/10.1016/j.cstp.2019.08.002

Flora, D.B., 2020. Your Coefficient Alpha Is Probably Wrong, but Which Coefficient Omega Is Right? A Tutorial on Using R to Obtain Better Reliability Estimates. Advances in Methods and Practices in Psychological Science 3, 484–501. https://doi.org/10.1177/2515245920951747

Fluctuo, 2022. European shared mobility Index Q2 2022.

Ganapati, S., Reddick, C.G., 2018. Prospects and challenges of sharing economy for the public sector. Government Information Quarterly 35, 77–87. https://doi.org/10.1016/j.giq.2018.01.001

Garcia, C.S.H.F., Macário, R., Menezes, E.D.D.A.G., Loureiro, C.F.G., 2018. Strategic Assessment of Lisbon’s Accessibility and Mobility Problems from an Equity Perspective. Netw Spat Econ 18, 415–439. https://doi.org/10.1007/s11067-018-9391-4

García-Palomares, J.C., Gutiérrez, J., Cardozo, O.D., 2013. Walking Accessibility to Public Transport: An Analysis Based on Microdata and GIS. Environ Plann B Plann Des 40, 1087–1102. https://doi.org/10.1068/b39008

Gartner, 2022. What is a Supper-app? URL https://www.gartner.com/en/articles/what-is-a-superapp

Geels, F.W., 2020. Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. Technological Forecasting and Social Change 152, 119894. https://doi.org/10.1016/j.techfore.2019.119894

Geels, F.W., 2014. Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. Theory, Culture & Society 31, 21–40. https://doi.org/10.1177/0263276414531627

Geels, F.W., 2012. A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. Journal of Transport Geography 24, 471–482. https://doi.org/10.1016/j.jtrangeo.2012.01.021

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy 31, 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Gjaltema, J., Biesbroek, R., Termeer, K., 2020. From government to governance…to meta-governance: a systematic literature review. Public Management Review 22, 1760–1780. https://doi.org/10.1080/14719037.2019.1648697

Gompf, K., Traverso, M., Hetterich, J., 2020. Towards social life cycle assessment of mobility services: systematic literature review and the way forward. Int J Life Cycle Assess 25, 1883–1909. https://doi.org/10.1007/s11367-020-01788-8

Goralzik, A., König, A., Alčiauskaitė, L., Hatzakis, T., 2022. Shared mobility services: an accessibility assessment from the perspective of people with disabilities. Eur. Transp. Res. Rev. 14, 34. https://doi.org/10.1186/s12544-022-00559-w

Gordon, J.-S., Fomin, V.V., 2019. Ethics and Standardization, in: Advances in Human Resources Management and Organizational Development. IGI Global, pp. 177–192. https://doi.org/10.4018/978-1-5225-9008-8.ch009

Gössling, S., 2016. Urban transport justice. Journal of Transport Geography 54, 1–9. https://doi.org/10.1016/j.jtrangeo.2016.05.002

Grengs, J., 2012. Equity and the social distribution of job accessibility in Detroit. Environ. Plann. B 39, 785–800. https://doi.org/10.1068/b36097

Handy, S., Cao, X., Mokhtarian, P., 2005. Correlation or causality between the built environment and travel behavior? Evidence from Northern California. Transportation Research Part D: Transport and Environment 10, 427–444. https://doi.org/10.1016/j.trd.2005.05.002

Hasselwander, M., Bigotte, J.F., 2023. Mobility as a Service (MaaS) in the Global South: research findings, gaps, and directions. Eur. Transp. Res. Rev. 15, 27. https://doi.org/10.1186/s12544-023-00604-2

Hasselwander, M., Bigotte, J.F., 2022. Transport Authorities and Innovation: Understanding Barriers for MaaS Implementation in the Global South. Transportation Research Procedia 62, 475–482. https://doi.org/10.1016/j.trpro.2022.02.059

Hasselwander, M., Nieland, S., Dematera-Contreras, K., Goletz, M., 2023. MaaS for the masses: Potential transit accessibility gains and required policies under Mobility-as-a-Service. Multimodal Transportation 2, 100086. https://doi.org/10.1016/j.multra.2023.100086

Hauslbauer, A.L., Schade, J., Petzoldt, T., 2022. The identification of mobility types on a national level. Transport Policy 125, 289–298. https://doi.org/10.1016/j.tranpol.2022.06.013

Hayes, A.F., Coutts, J.J., 2020. Use Omega Rather than Cronbach's Alpha for Estimating Reliability. But…. Communication Methods and Measures 14, 1–24. https://doi.org/10.1080/19312458.2020.1718629

Heikkilä, S., 2014. Mobility as a Service – A Proposal for Action for the Public Administration Case Helsinki. Aalto University. School of Engineering 8.

Hensher, D.A., 2022. The reason MaaS is such a challenge: A note. Transport Policy 129, 137–139. https://doi.org/10.1016/j.tranpol.2022.10.008

Hensher, D.A., Hietanen, S., 2022. Mobility as a feature (MaaF): rethinking the focus of the second generation of mobility as a service (MaaS). Transport Reviews 1–5. https://doi.org/10.1080/01441647.2022.2159122

Hensher, D.A., Ho, C.Q., Reck, D.J., 2021a. Mobility as a service and private car use: Evidence from the Sydney MaaS trial. Transportation Research Part A: Policy and Practice 145, 17–33. https://doi.org/10.1016/j.tra.2020.12.015

Hensher, D.A., Mulley, C., Nelson, J.D., 2023. What is an ideal (Utopian) mobility as a service (MaaS) framework? A communication note. Transportation Research Part A: Policy and Practice 172, 103675. https://doi.org/10.1016/j.tra.2023.103675

Hensher, D.A., Mulley, C., Nelson, J.D., 2021b. Mobility as a service (MaaS) – Going somewhere or nowhere? Transport Policy 111, 153–156. https://doi.org/10.1016/j.tranpol.2021.07.021

Hensher, D.A., Nelson, J.D., Mulley, C., 2022. Electric car sharing as a service (ECSaaS) – Acknowledging the role of the car in the public mobility ecosystem and what it might mean for MaaS as eMaaS? Transport Policy 116, 212–216. https://doi.org/10.1016/j.tranpol.2021.12.007

Hesselgren, M., Sjöman, M., Pernestål, A., 2020. Understanding user practices in mobility service systems: Results from studying large scale corporate MaaS in practice. Travel Behaviour and Society 21, 318–327. https://doi.org/10.1016/j.tbs.2018.12.005

Hidayati, I., Tan, W., Yamu, C., 2021. Conceptualizing Mobility Inequality: Mobility and Accessibility for the Marginalized. Journal of Planning Literature 36, 492–507. https://doi.org/10.1177/08854122211012898

Hietanen, S., 2023. “We needed better dreams.” ITS International.

Hietanen, S., 2014. ‘Mobility as a Service’ – the new transport model? Eurotransport 12, 2–4.

Hirschhorn, F., Paulsson, A., Sørensen, C.H., Veeneman, W., 2019. Public transport regimes and mobility as a service: Governance approaches in Amsterdam, Birmingham, and Helsinki. Transportation Research Part A: Policy and Practice 130, 178–191. https://doi.org/10.1016/j.tra.2019.09.016

Ho, C.Q., 2022. Can MaaS change users' travel behaviour to deliver commercial and societal outcomes? Transportation Research Part A: Policy and Practice 165, 76–97. https://doi.org/10.1016/j.tra.2022.09.004

Ho, C.Q., Hensher, D.A., Mulley, C., Wong, Y.Z., 2018. Potential uptake and willingness-to-pay for Mobility as a Service (MaaS): A stated choice study. Transportation Research Part A: Policy and Practice 117, 302–318. https://doi.org/10.1016/j.tra.2018.08.025

Ho, C.Q., Hensher, D.A., Reck, D.J., Lorimer, S., Lu, I., 2021. MaaS bundle design and implementation: Lessons from the Sydney MaaS trial. Transportation Research Part A: Policy and Practice 149, 339–376. https://doi.org/10.1016/j.tra.2021.05.010

Hook, H., De Vos, J., Van Acker, V., Witlox, F., 2023. Evolutions in undirected travel (satisfaction) during the COVID-19 pandemic. Transportation Research Part F: Traffic Psychology and Behaviour 94, 99–113. https://doi.org/10.1016/j.trf.2023.01.025

Hult, Å., Perjo, L., Smith, G., 2021. Shared Mobility in Rural Contexts: Organizational Insights from Five Mobility-as-a-Service Pilots in Sweden. Sustainability 13, 10134. https://doi.org/10.3390/su131810134

Iancu, I., Iancu, B., 2020. Designing mobile technology for elderly. A theoretical overview. Technological Forecasting and Social Change 155, 119977. https://doi.org/10.1016/j.techfore.2020.119977

INE, 2021. Censos 2021.

Jahangir, S., Bailey, A., Hasan, M.U., Hossain, S., 2024. "We do not go outside, though We want to": Unequal Access to Public Transport and Transport-Related Social Exclusion of Older Adults in Dhaka, Bangladesh. J Appl Gerontol 43, 1165–1176. https://doi.org/10.1177/07334648241231156

James, J., 2021. Confronting the scarcity of digital skills among the poor in developing countries. Development Policy Review 39, 324–339. https://doi.org/10.1111/dpr.12479

Jessop, B., 2002. Liberalism, Neoliberalism, and Urban Governance: A State–Theoretical Perspective. Antipode 34, 452–472. https://doi.org/10.1111/1467-8330.00250

Jiao, J., Wang, F., 2021. Shared mobility and transit-dependent population: A new equity opportunity or issue? International Journal of Sustainable Transportation 15, 294–305. https://doi.org/10.1080/15568318.2020.1747578

Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M.J.A., Narayan, J., 2017. Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. UP 2, 13–25. https://doi.org/10.17645/up.v2i2.931

Jittrapirom, P., Marchau, V., van der Heijden, R., Meurs, H., 2020. Future implementation of mobility as a service (MaaS): Results of an international Delphi study. Travel Behaviour and Society 21, 281–294. https://doi.org/10.1016/j.tbs.2018.12.004

Kamargianni, M., 2015. Feasibility Study for "Mobility as a Service" concept in London. https://doi.org/10.13140/RG.2.1.3808.1124

Kamargianni, M., Li, W., Matyas, M., Schäfer, A., 2016. A Critical Review of New Mobility Services for Urban Transport. Transportation Research Procedia 14, 3294–3303. https://doi.org/10.1016/j.trpro.2016.05.277

Kanuri, C., Venkat, K., Maiti, S., Mulukutla, P., 2019. Leveraging innovation for last-mile connectivity to mass transit. Transportation Research Procedia 41, 655–669. https://doi.org/10.1016/j.trpro.2019.09.114

Karlsson, I.C.M., Mukhtar-Landgren, D., Smith, G., Koglin, T., Kronsell, A., Lund, E., Sarasini, S., Sochor, J., 2020. Development and implementation of Mobility-as-a-Service – A qualitative study of barriers and enabling factors. Transportation Research Part A: Policy and Practice 131, 283–295. https://doi.org/10.1016/j.tra.2019.09.028

Karlsson, I.C.M., Sochor, J., Strömberg, H., 2016. Developing the 'Service' in Mobility as a Service: Experiences from a Field Trial of an Innovative Travel Brokerage. Transportation Research Procedia 14, 3265–3273. https://doi.org/10.1016/j.trpro.2016.05.273

Kelly, S., Kaye, S.-A., Oviedo-Trespalacios, O., 2023. What factors contribute to the acceptance of artificial intelligence? A systematic review. Telematics and Informatics 77, 101925. https://doi.org/10.1016/j.tele.2022.101925

Khaddar, S., Rahman Fatmi, M., 2024. Modeling Telecommuting and Teleshopping Preferences in the Post-Pandemic Era. Transportation Research Record: Journal of the Transportation Research Board 03611981231222238. https://doi.org/10.1177/03611981231222238

Kim, S., Rasouli, S., 2022. The influence of latent lifestyle on acceptance of Mobility-as-a-Service (MaaS): A hierarchical latent variable and latent class approach. Transportation Research Part A: Policy and Practice 159, 304–319. https://doi.org/10.1016/j.tra.2022.03.020

Kloeke, J., 2020. Mobility as a Service from an equity perspective.

Kooiman, J. (Ed.), 2010. Modern governance: new government-society interactions. Sage, London Newbury Park, Calif.

Kopplin, C.S., Brand, B.M., Reichenberger, Y., 2021. Consumer acceptance of shared e-scooters for urban and short-distance mobility. Transportation Research Part D: Transport and Environment 91, 102680. https://doi.org/10.1016/j.trd.2020.102680

Korkmaz, H., Fidanoglu, A., Ozcelik, S., Okumus, A., 2021. User Acceptance of Autonomous Public Transport Systems (APTS): Extended UTAUT2 Model. JPT 23. https://doi.org/10.5038/2375-0901.23.1.5

Krauss, K., Reck, D.J., Axhausen, K.W., 2023. How does transport supply and mobility behaviour impact preferences for MaaS bundles? A multi-city approach. Transportation Research Part C: Emerging Technologies 147, 104013. https://doi.org/10.1016/j.trc.2023.104013

Kriswardhana, W., Esztergár-Kiss, D., 2025. The role of intermodality and environmental consciousness in the preferences for MaaS bundles: A hybrid choice modeling approach. Transportation Research Part A: Policy and Practice 191, 104332. https://doi.org/10.1016/j.tra.2024.104332

Kriswardhana, W., Esztergár-Kiss, D., 2024. Segmenting the potential users of MaaS by combining latent class cluster analysis and structural equation modeling. Sustainable Cities and Society 114, 105764. https://doi.org/10.1016/j.scs.2024.105764

Kriswardhana, W., Esztergár-Kiss, D., 2023a. A systematic literature review of Mobility as a Service: Examining the socio-technical factors in MaaS adoption and bundling packages. Travel Behaviour and Society 31, 232–243. https://doi.org/10.1016/j.tbs.2022.12.007

Kriswardhana, W., Esztergár-Kiss, D., 2023b. Exploring the aspects of MaaS adoption based on college students' preferences. Transport Policy 136, 113–125. https://doi.org/10.1016/j.tranpol.2023.03.018

Kuss, P., Nicholas, K.A., 2022. A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management. Case Studies on Transport Policy 10, 1494–1513. https://doi.org/10.1016/j.cstp.2022.02.001

Lajas, R., Macário, R., 2020. Public policy framework supporting "mobility-as-a-service" implementation. Research in Transportation Economics 83, 100905. https://doi.org/10.1016/j.retrec.2020.100905

Larco, N., Vedder, K., Heezen, M., 2024. Public Mobility: The next Evolution of MaaS. TNO: Innovation for life.

Li, S., Zhai, W., Jiao, J., Wang, C. (Kenneth), 2022. Who loses and who wins in the ride-hailing era? A case study of Austin, Texas. Transport Policy 120, 130–138. https://doi.org/10.1016/j.tranpol.2022.03.009

Li, Y., 2019. The Role of Public Authorities in the Development of Mobility-as-a-Service, in: Finger, M., Audouin, M. (Eds.), The Governance of Smart Transportation Systems, The Urban Book Series. Springer International Publishing, Cham, pp. 229–245. https://doi.org/10.1007/978-3-319-96526-0_12

Li, Y., Cook, S., May, A., 2020. Understanding the Exclusion Issues of Mobility-as-a-Service (MaaS): The Potential Problems of Older Travellers' Involvement, in: Gao, Q., Zhou, J. (Eds.), Human Aspects of IT for the Aged Population. Technology and Society, Lecture Notes in Computer Science. Springer International Publishing, Cham, pp. 269–287. https://doi.org/10.1007/978-3-030-50232-4_19

Li, Y., Voege, T., 2017a. Mobility as a Service (MaaS): Challenges of Implementation and Policy Required. JTTs 07, 95–106. https://doi.org/10.4236/jtts.2017.72007

Li, Y., Voege, T., 2017b. Mobility as a Service (MaaS): Challenges of Implementation and Policy Required. Journal of Transportation Technologies 07, 95–106. https://doi.org/10.4236/jtts.2017.72007

Liu, R., Palm, M., Shalaby, A., Farber, S., 2020. A social equity lens on bus bridging and ride-hailing responses to unplanned subway disruptions. Journal of Transport Geography 88, 102870. https://doi.org/10.1016/j.jtrangeo.2020.102870

Lopes, A.S., Orozco-Fontalvo, M., Moura, F., Vale, D., 2023. Mobility as a service and socio-territorial inequalities: A systematic literature review. JTLU 16, 215–240. https://doi.org/10.5198/jtlu.2023.2273

Lopez-Carreiro, I., Monzon, A., Lopez, E., 2024. Assessing the intention to uptake MaaS: the case of Randstad. Eur. Transp. Res. Rev. 16, 2. https://doi.org/10.1186/s12544-023-00625-x

Lopez-Carreiro, I., Monzon, A., Lopez, E., Lopez-Lambas, M.E., 2020. Urban mobility in the digital era: An exploration of travellers' expectations of MaaS mobile-technologies. Technology in Society 63, 101392. https://doi.org/10.1016/j.techsoc.2020.101392

Loubser, J., Marnewick, A.L., Joseph, N., 2021. Framework for the potential userbase of mobility as a service. Research in Transportation Business & Management 39, 100583. https://doi.org/10.1016/j.rtbm.2020.100583

Lowry, J.H., Lowry, M.B., 2014. Comparing spatial metrics that quantify urban form. Computers, Environment and Urban Systems 44, 59–67. https://doi.org/10.1016/j.compenvurbsys.2013.11.005

Lucas, K., 2019. A new evolution for transport-related social exclusion research? Journal of Transport Geography 81, 102529. https://doi.org/10.1016/j.jtrangeo.2019.102529

Lucas, K., 2012. Transport and social exclusion: Where are we now? Transport Policy 20, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013

Lucas, K., Mattioli, G., Verlinghieri, E., Guzman, A., 2016. Transport poverty and its adverse social consequences. Proceedings of the Institution of Civil Engineers - Transport 169, 353–365. https://doi.org/10.1680/jtran.15.00073

Lucas, K., Musso, A., 2014. Policies for social inclusion in transportation: An introduction to the special issue. Case Studies on Transport Policy 2, 37–40. https://doi.org/10.1016/j.cstp.2014.06.002

Lyons, G., Hammond, P., Mackay, K., 2019. The importance of user perspective in the evolution of MaaS. Transportation Research Part A: Policy and Practice 121, 22–36. https://doi.org/10.1016/j.tra.2018.12.010

MaaS Scotland, 2024. Implementing Mobility as a Service: A Roadmap for Scotland.

Macário, R., 2011. Simplifying Complexity in Urban Mobility Systems, in: Managing Urban Mobility Systems. Emerald Group Publishing Limited, pp. 79–136. https://doi.org/10.1108/9780857246127-003

Mackett, R.L., Thoreau, R., 2015. Transport, social exclusion and health. Journal of Transport & Health 2, 610–617. https://doi.org/10.1016/j.jth.2015.07.006

Marôco, J., 2010. Análise de equações estruturais: Fundamentos teóricos, software e aplicações.

Martens, K., Bastiaanssen, J., Lucas, K., 2019. Measuring transport equity: Key components, framings and metrics, in: Measuring Transport Equity. Elsevier, pp. 13–36. https://doi.org/10.1016/B978-0-12-814818-1.00002-0

Matowicki, M., Amorim, M., Kern, M., Pecherkova, P., Motzer, N., Pribyl, O., 2022. Understanding the potential of MaaS – An European survey on attitudes. Travel Behaviour and Society 27, 204–215. https://doi.org/10.1016/j.tbs.2022.01.009

Matyas, M., Kamargianni, M., 2019. The potential of mobility as a service bundles as a mobility management tool. Transportation 46, 1951–1968. https://doi.org/10.1007/s11116-018-9913-4

McIlroy, R.C., 2023. Mobility as a service and gender: A review with a view. Travel Behaviour and Society 32, 100596. https://doi.org/10.1016/j.tbs.2023.100596

Meadowcroft, J., 2011. Engaging with the politics of sustainability transitions. Environmental Innovation and Societal Transitions 1, 70–75. https://doi.org/10.1016/j.eist.2011.02.003

Meurs, H., Sharmeen, F., Marchau, V., van der Heijden, R., 2020. Organizing integrated services in mobility-as-a-service systems: Principles of alliance formation applied to a MaaS-pilot in the Netherlands. Transportation Research Part A: Policy and Practice 131, 178–195. https://doi.org/10.1016/j.tra.2019.09.036

Minow, M., 2021. EQUALITY VS. EQUITY. American Journal of Law and Equality 1, 167–193. https://doi.org/10.1162/ajle_a_00019

Mladenović, M.N., Haavisto, N., 2021. Interpretative flexibility and conflicts in the emergence of Mobility as a Service: Finnish public sector actor perspectives. Case Studies on Transport Policy 9, 851–859. https://doi.org/10.1016/j.cstp.2021.04.005

Moscholidou, I., Pangbourne, K., 2020. A preliminary assessment of regulatory efforts to steer smart mobility in London and Seattle. Transport Policy 98, 170–177. https://doi.org/10.1016/j.tranpol.2019.10.015

Mulley, C., Nelson, J.D., Ho, C., Hensher, D.A., 2023. MaaS in a regional and rural setting: Recent experience. Transport Policy 133, 75–85. https://doi.org/10.1016/j.tranpol.2023.01.014

Narupiti, S., 2019. Exploring the possibility of MaaS service in Thailand, implications from the existing conditions and experts' opinions on "Who should be the MaaS provider in Bangkok?" IATSS Research 43, 226–234. https://doi.org/10.1016/j.iatssr.2019.11.003

Ng, W.-S., Acker, A., 2018. Understanding Urban Travel Behaviour by Gender for Efficient and Equitable Transport Policies. ITF Discussion papers.

Nguyen-Phuoc, D.Q., Truong, T.M., Nguyen, M.H., Pham, H.-G., Li, Z.-C., Oviedo-Trespalacios, O., 2024. What factors influence the intention to use electric motorcycles in motorcycle-dominated countries? An empirical study in Vietnam. Transport Policy 146, 193–204. https://doi.org/10.1016/j.tranpol.2023.11.013

Nguyen-Phuoc, D.Q., Vo, N.S., Su, D.N., Nguyen, V.H., Oviedo-Trespalacios, O., 2021. What makes passengers continue using and talking positively about ride-hailing services? The role of the booking app and post-booking service quality. Transportation Research Part A: Policy and Practice 150, 367–384. https://doi.org/10.1016/j.tra.2021.06.013

Nordhoff, S., Louw, T., Innamaa, S., Lehtonen, E., Beuster, A., Torrao, G., Bjorvatn, A., Kessel, T., Malin, F., Happee, R., Merat, N., 2020. Using the UTAUT2 model to explain public acceptance of conditionally automated (L3) cars: A questionnaire study among 9,118 car drivers from eight European countries. Transportation Research Part F: Traffic Psychology and Behaviour 74, 280–297. https://doi.org/10.1016/j.trf.2020.07.015

Núñez, C., Antoniou, C., 2025. The Mobility as a Service Potential Index (MaaSPI): Assessing the conditions for MaaS across countries based on public sources. Research in Transportation Business & Management 60, 101360. https://doi.org/10.1016/j.rtbm.2025.101360

Orozco-Fontalvo, M., Llerena, L., Cantillo, V., 2022. Dockless electric scooters: A review of a growing micromobility mode. International Journal of Sustainable Transportation 1–17. https://doi.org/10.1080/15568318.2022.2044097

Orozco-Fontalvo, M., Llerena-Sierra, L., Cantillo, V., 2024a. E-scooters: how do latent and socioeconomic factors affect their usage in the global south? Implications for policy planning. Transportation Planning and Technology 1–21. https://doi.org/10.1080/03081060.2024.2359492

Orozco-Fontalvo, M., Lopes, A.S., Vale, D., Moura, F., 2025. MaaS: Which resources are enablers, and who is being excluded? Transportation Research Part D: Transport and Environment 148, 104990. https://doi.org/10.1016/j.trd.2025.104990

Orozco-Fontalvo, M., Moura, F., 2025. Should MaaS bundles include home delivery services? Transportation Research Procedia 86, 136–143. https://doi.org/10.1016/j.trpro.2025.04.018

Orozco-Fontalvo, M., Moura, F., 2023. Refocusing MaaS approach: A brief. Transport Policy 141, 340–342. https://doi.org/10.1016/j.tranpol.2023.08.002

Orozco-Fontalvo, M., Soares Lopes, A., Vale, D., Moura, F., 2024b. IMPReSS: A comprehensive method to classify MaaS systems. Transport Policy 155, 234–241. https://doi.org/10.1016/j.tranpol.2024.07.005

Ouzzani, M., Hammady, H., Fedorowicz, Z., Elmagarmid, A., 2016. Rayyan—a web and mobile app for systematic reviews. Syst Rev 5, 210. https://doi.org/10.1186/s13643-016-0384-4

Oviedo-Trespalacios, O., Rubie, E., Haworth, N., 2022. Risky business: Comparing the riding behaviours of food delivery and private bicycle riders. Accident Analysis & Prevention 177, 106820. https://doi.org/10.1016/j.aap.2022.106820

Palmateer, C., Levinson, D., 2017. Justice, Exclusion, and Equity: An Analysis of 48 U.S. Metropolitan Areas. Retrieved from the University Digital Conservancy. Retrieved from the University Digital Conservancy.

Palmer, K., Tate, J.E., Wadud, Z., Nellthorp, J., 2018. Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. Applied Energy 209, 108–119. https://doi.org/10.1016/j.apenergy.2017.10.089

Pangbourne, K., Mladenović, M.N., Stead, D., Milakis, D., 2020a. Questioning mobility as a service: Unanticipated implications for society and governance. Transportation Research Part A: Policy and Practice 131, 35–49. https://doi.org/10.1016/j.tra.2019.09.033

Pangbourne, K., Mladenović, M.N., Stead, D., Milakis, D., 2020b. Questioning mobility as a service: Unanticipated implications for society and governance. Transportation Research Part A: Policy and Practice 131, 35–49. https://doi.org/10.1016/j.tra.2019.09.033

Pereira, R.H.M., Schwanen, T., Banister, D., 2017. Distributive justice and equity in transportation. Transport Reviews 37, 170–191. https://doi.org/10.1080/01441647.2016.1257660

Pickford, A., Chung, E., 2019. The shape of MaaS: The potential for MaaS Lite. IATSS Research 43, 219–225. https://doi.org/10.1016/j.iatssr.2019.11.006

Prieto-Curiel, R., Ospina, J.P., 2024. The ABC of mobility. Environment International 185, 108541. https://doi.org/10.1016/j.envint.2024.108541

Pritchard, J.P., Moura, F., Silva, J. de A. e, Martinez, L.M., 2014. Spatial Analysis of Transportation-related Social Exclusion in the Lisbon Metropolitan Area. Procedia - Social and Behavioral Sciences 111, 440–449. https://doi.org/10.1016/j.sbspro.2014.01.077

Qiao, S., Yeh, A.G.-O., 2021. Is ride-hailing a valuable means of transport in newly developed areas under TOD-oriented urbanization in China? Evidence from Chengdu City. Journal of Transport Geography 96, 103183. https://doi.org/10.1016/j.jtrangeo.2021.103183

Ritchie, H., Roser, M., 2019. Age structure. Published online at OurWorldinData.org.

Rogers, E.M., 2003. Diffusion of innovations, Fifth edition. ed. Free Press, New York London Toronto Sydney.

Rosano, A., Mancini, F., Solipaca, A., 2009. Poverty in People with Disabilities: Indicators from the Capability Approach. Soc Indic Res 94, 75–82. https://doi.org/10.1007/s11205-008-9337-1

Rosseel, Y., 2012. **lavaan** : An *R* Package for Structural Equation Modeling. J. Stat. Soft. 48. https://doi.org/10.18637/jss.v048.i02

Samadzad, M., Nosratzadeh, H., Karami, H., Karami, A., 2023. What are the factors affecting the adoption and use of electric scooter sharing systems from the end user's perspective? Transport Policy 136, 70–82. https://doi.org/10.1016/j.tranpol.2023.03.006

Santos, G., Nikolaev, N., 2021. Mobility as a Service and Public Transport: A Rapid Literature Review and the Case of Moovit. Sustainability 13, 3666. https://doi.org/10.3390/su13073666

Savitz, D.A., Wellenius, G.A., 2023. Can Cross-Sectional Studies Contribute to Causal Inference? It Depends. American Journal of Epidemiology 192, 514–516. https://doi.org/10.1093/aje/kwac037

Scheiner, J., Holz-Rau, C., 2017. Women's complex daily lives: a gendered look at trip chaining and activity pattern entropy in Germany. Transportation 44, 117–138. https://doi.org/10.1007/s11116-015-9627-9

Schikofsky, J., Dannewald, T., Kowald, M., 2020. Exploring motivational mechanisms behind the intention to adopt mobility as a service (MaaS): Insights from Germany. Transportation Research Part A: Policy and Practice 131, 296–312. https://doi.org/10.1016/j.tra.2019.09.022

Scott, W.R., 2014. Institutions and organizations: ideas, interests, and identities, Fourth edition. ed. SAGE, Los Angeles.

Sen, A., 1979a. Equality of What. Cambridge university press 1.

Sen, A., 1979b. Issues in the Measurement of Poverty. The Scandinavian Journal of Economics 81, 285. https://doi.org/10.2307/3439966

Sen, A., 1974. Informational bases of alternative welfare approaches. Journal of Public Economics 3, 387–403. https://doi.org/10.1016/0047-2727(74)90006-1

Sieck, C.J., Sheon, A., Ancker, J.S., Castek, J., Callahan, B., Siefer, A., 2021. Digital inclusion as a social determinant of health. npj Digit. Med. 4, 52. https://doi.org/10.1038/s41746-021-00413-8

Singh, M., 2020. India's shift from mass transit to MaaS transit: Insights from Kochi. Transportation Research Part A: Policy and Practice 131, 219–227. https://doi.org/10.1016/j.tra.2019.09.037

Siqueira, M., Grangeiro Loureiro, C.F., Soares Lopes, A., 2022. Diagnóstico das relações causa-efeito na mobilidade por gênero em grandes cidades brasileiras. TRANSPORTES 30. https://doi.org/10.14295/transportes.v29i3.2662

Smith, G., Hensher, D.A., 2020a. Towards a framework for Mobility-as-a-Service policies. Transport Policy 89, 54–65. https://doi.org/10.1016/j.tranpol.2020.02.004

Smith, G., Hensher, D.A., 2020b. Towards a framework for Mobility-as-a-Service policies. Transport Policy 89, 54–65. https://doi.org/10.1016/j.tranpol.2020.02.004

Smith, G., Hensher, D.A., 2020c. Towards a framework for Mobility-as-a-Service policies. Transport Policy 89, 54–65. https://doi.org/10.1016/j.tranpol.2020.02.004

Smith, G., Sochor, J., Karlsson, I.C.M., 2019. Public–private innovation: barriers in the case of mobility as a service in West Sweden. Public Management Review 21, 116–137. https://doi.org/10.1080/14719037.2018.1462399

Smith, G., Sochor, J., Karlsson, I.C.M., 2018a. Mobility as a Service: Development scenarios and implications for public transport. Research in Transportation Economics 69, 592–599. https://doi.org/10.1016/j.retrec.2018.04.001

Smith, G., Sochor, J., Sarasini, S., 2018b. Mobility as a service: Comparing developments in Sweden and Finland. Research in Transportation Business & Management 27, 36–45. https://doi.org/10.1016/j.rtbm.2018.09.004

Sochor, J., Arby, H., Karlsson, I.C.M., Sarasini, S., 2018a. A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. Research in Transportation Business & Management 27, 3–14. https://doi.org/10.1016/j.rtbm.2018.12.003

Sochor, J., Arby, H., Karlsson, I.C.M.A., Sarasini, S., 2018b. A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. Research in Transportation Business and Management 27, 3–14. https://doi.org/10.1016/j.rtbm.2018.12.003

Sochor, J., Karlsson, I.C.M.A., Strömberg, H., 2016. Trying out mobility as a service: Experiences from a field trial and implications for understanding demand. Transportation Research Record 2542, 57–64. https://doi.org/10.3141/2542-07

Sørensen, E., Torfing, J., 2009. MAKING GOVERNANCE NETWORKS EFFECTIVE AND DEMOCRATIC THROUGH METAGOVERNANCE. Public Administration 87, 234–258. https://doi.org/10.1111/j.1467-9299.2009.01753.x

Sørensen, E., Torfing, J. (Eds.), 2008. Theories of democratic network governance, 1. publ. in paperback. ed. Palgrave Macmillan, Basingstoke.

Sorensen, E., Torfing, J., 2005. The Democratic Anchorage of Governance Networks. Scand Pol Studs 28, 195–218. https://doi.org/10.1111/j.1467-9477.2005.00129.x

Soto, J., Orozco-Fontalvo, M., Useche, S.A., 2022. Public transportation and fear of crime at BRT Systems: Approaching to the case of Barranquilla (Colombia) through integrated choice and latent variable models. Transportation Research Part A: Policy and Practice 155, 142–160. https://doi.org/10.1016/j.tra.2021.11.001

Sovacool, B.K., Daniels, C., AbdulRafiu, A., 2022. Transitioning to electrified, automated and shared mobility in an African context: A comparative review of Johannesburg, Kigali, Lagos and Nairobi. Journal of Transport Geography 98, 103256. https://doi.org/10.1016/j.jtrangeo.2021.103256

Sperling, D. (Ed.), 2018. Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future. Island Press/Center for Resource Economics, Washington, DC. https://doi.org/10.5822/978-1-61091-906-7

Spurlock, C.A., Todd-Blick, A., Wong-Parodi, G., Walker, V., 2020. Children, Income, and the Impact of Home Delivery on Household Shopping Trips. Transportation Research Record 2674, 335–350. https://doi.org/10.1177/0361198120935113

Storme, T., Casier, C., Azadi, H., Witlox, F., 2021. Impact Assessments of New Mobility Services: A Critical Review. Sustainability 13, 3074. https://doi.org/10.3390/su13063074

Storme, T., De Vos, J., De Paepe, L., Witlox, F., 2020. Limitations to the car-substitution effect of MaaS. Findings from a Belgian pilot study. Transportation Research Part A: Policy and Practice 131, 196–205. https://doi.org/10.1016/j.tra.2019.09.032

Strömberg, H., Karlsson, I.C.M., Sochor, J., 2018. Inviting travelers to the smorgasbord of sustainable urban transport: evidence from a MaaS field trial. Transportation 45, 1655–1670. https://doi.org/10.1007/s11116-018-9946-8

Sunzi, Butler-Bowdon, T., Calthrop, E.F., Wu, Q., 2010. The art of war: including the translated The sayings of Wu Tzu. Capstone, West Sussex, United Kingdom.

Tarduno, M., 2021. The congestion costs of Uber and Lyft. Journal of Urban Economics 122, 103318. https://doi.org/10.1016/j.jue.2020.103318

Throughout the rich world, the young are falling out of love with cars, n.d.

Tiikkaja, H., Liimatainen, H., 2021. Car access and travel behaviour among men and women in car deficient households with children. Transportation Research Interdisciplinary Perspectives 10, 100367. https://doi.org/10.1016/j.trip.2021.100367

Tirachini, A., 2020. Ride-hailing, travel behaviour and sustainable mobility: an international review. Transportation 47, 2011–2047. https://doi.org/10.1007/s11116-019-10070-2

Toyama, M., 2022. Empirical Study on the Acceptance of Mobility as a Service (MaaS) Based on the UTAUT2 Model. Asia Marketing Journal 24, 121–130. https://doi.org/10.53728/2765-6500.1593

Tranter, P.J., 2010. Speed Kills: The Complex Links Between Transport, Lack of Time and Urban Health. J Urban Health 87, 155–166. https://doi.org/10.1007/s11524-009-9433-9

Tsouros, I., Tsirimpa, A., Pagoni, I., Polydoropoulou, A., 2021. MaaS users: Who they are and how much they are willing-to-pay. Transportation Research Part A: Policy and Practice 148, 470–480. https://doi.org/10.1016/j.tra.2021.04.016

Turoń, K., 2022. Complaints Analysis as an Opportunity to Counteract Social Transport Exclusion in Shared Mobility Systems. Smart Cities 5, 875–888. https://doi.org/10.3390/smartcities5030044

Understanding Mobility as a Service (MaaS), 2020. . Elsevier. https://doi.org/10.1016/C2019-0-00508-0

UNDP, GNPT, 2024. A Closer Look at Informal (Popular) Transportation: An Emerging Portrait.

Useche, S., Robayo, S., Orozco-Fontalvo, M., 2024. The hidden cost of your ‘too fast food’: Stress-related factors and fatigue predict food delivery riders’ occupational crashes. International

Journal of Occupational Safety and Ergonomics (JOSE). https://doi.org/10.1080/10803548.2024.2356997

Useche, S.A., Gonzalez-Marin, A., Faus, M., Alonso, F., 2022. Environmentally friendly, but behaviorally complex? A systematic review of e-scooter riders' psychosocial risk features. PLoS ONE 17, e0268960. https://doi.org/10.1371/journal.pone.0268960

Useche, S.A., Marin, C., Llamazares, F.J., 2023. "Another (hard) day moving in the city": Development and validation of the MCSS, a multimodal commuting stress scale. Transportation Research Part F: Traffic Psychology and Behaviour 95, 143–159. https://doi.org/10.1016/j.trf.2023.04.005

Vale, D., 2020. Effective accessibility: Using effective speed to measure accessibility by cost. Transportation Research Part D: Transport and Environment 80, 102263. https://doi.org/10.1016/j.trd.2020.102263

Vale, D.S., Saraiva, M., Pereira, M., 2015a. Active accessibility: A review of operational measures of walking and cycling accessibility. JTLU. https://doi.org/10.5198/jtlu.2015.593

Vale, D.S., Saraiva, M., Pereira, M., 2015b. Active accessibility: A review of operational measures of walking and cycling accessibility. JTLU. https://doi.org/10.5198/jtlu.2015.593

Van De Schoot, R., Lugtig, P., Hox, J., 2012. A checklist for testing measurement invariance. European Journal of Developmental Psychology 9, 486–492. https://doi.org/10.1080/17405629.2012.686740

Van Droogenbroeck, E., Van Hove, L., 2017. Adoption of Online Grocery Shopping: Personal or Household Characteristics? Journal of Internet Commerce 16, 255–286. https://doi.org/10.1080/15332861.2017.1317149

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

Venkatesh, V., Davis, F.D., 2000. A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Management Science 46, 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926

Venkatesh, V., Morris, M., Gordon, D., Davis, F., 2003. User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly 27.

Vianna, E., 2024. Uber Eats, Bolt Food e Glovo lideram as reclamações no Portal da Queixa em matéria de serviços de entregas ao domicílio. Os clientes queixam-se de pedidos que não foram entregues, problemas com reembolsos e atrasos e erros nas entregas. Journal de Noticias.

Vij, A., Dühr, S., 2022. The commercial viability of Mobility-as-a-Service (MaaS): what’s in it for existing transport operators, and why should governments intervene? Transport Reviews 1–22. https://doi.org/10.1080/01441647.2022.2028032

Visser, J., Nemoto, T., Browne, M., 2014. Home Delivery and the Impacts on Urban Freight Transport: A Review. Procedia - Social and Behavioral Sciences 125, 15–27. https://doi.org/10.1016/j.sbspro.2014.01.1452

Wang, X., Cheng, Z., 2020. Cross-Sectional Studies: Strengths, Weaknesses, and Recommendations. Chest 158, S65–S71. https://doi.org/10.1016/j.chest.2020.03.012

Wang, X., Shao, C., Yin, C., Zhuge, C., 2018. Exploring the Influence of Built Environment on Car Ownership and Use with a Spatial Multilevel Model: A Case Study of Changchun, China. IJERPH 15, 1868. https://doi.org/10.3390/ijerph15091868

Washington, S., 2020. Statistical and econometric methods for transportation data analysis: Simon Washington, Matthew Karlaftis, Fred Mannering, Panagiotis Anastasopoulos, Third Edition. ed, Chapman and Hall/CRC Interdisciplinary Statistics Series. CRC Press Taylor & Francis Group, Boca Raton London New York.

Wee, B.V., Wee, B.V., Geurs, K., 2011. Discussing Equity and Social Exclusion in Accessibility Evaluations. European Journal of Transport and Infrastructure Research. https://doi.org/10.18757/EJTIR.2011.11.4.2940

Windhoff-Héritier, A. (Ed.), 2002. Common goods: reinventing European and international governance, Governance in Europe. Rowman & Littlefield Publishers, Lanham, Md.

Wong, S.D., Broader, J.C., Shaheen, S.A., 2020. Can Sharing Economy Platforms Increase Social Equity for Vulnerable Populations in Disaster Response and Relief? A Case Study of the 2017 and 2018 California Wildfires. Transportation Research Interdisciplinary Perspectives 5, 100131. https://doi.org/10.1016/j.trip.2020.100131

Yan, X., Zhao, X., Han, Y., Hentenryck, P.V., Dillahunt, T., 2021. Mobility-on-demand versus fixed-route transit systems: An evaluation of traveler preferences in low-income communities. Transportation Research Part A: Policy and Practice 148, 481–495. https://doi.org/10.1016/j.tra.2021.03.019

Zhang, N., Yang, Q., 2024. Public transport inclusion and active aging: A systematic review on elderly mobility. Journal of Traffic and Transportation Engineering (English Edition) 11, 312–347. https://doi.org/10.1016/j.jtte.2024.04.001

Zhang, Y., Li, X., Wang, S., Yao, Y., Li, Q., Tu, W., Zhao, Hongfang, Zhao, Hui, Feng, K., Sun, L., Hubacek, K., 2021. A global North-South division line for portraying urban development. iScience 24, 102729. https://doi.org/10.1016/j.isci.2021.102729

Zhang, Z., Zhang, N., 2021. A Novel Development Scheme of Mobility as a Service: Can It Provide a Sustainable Environment for China? Sustainability 13, 4233. https://doi.org/10.3390/su13084233

Zhao, X., Vaddadi, B., Sjöman, M., Hesselgren, M., Pernestål, A., 2020. Key barriers in MaaS development and implementation: Lessons learned from testing Corporate MaaS (CMaaS). Transportation Research Interdisciplinary Perspectives 8, 100227. https://doi.org/10.1016/j.trip.2020.100227

Zhao, Z., Sun, Y., He, Y., Li, Y., 2023. The application potential of Mobility as a Service (MaaS) at mega events: A case study of Hangzhou 2022 Asian Games. Journal of Cleaner Production 427, 139211. https://doi.org/10.1016/j.jclepro.2023.139211

Zhong, L., Lee, B., 2017. Carless or Car Later?: Declining Car Ownership of Millennial Households in the Puget Sound Region, Washington State. Transportation Research Record 2664, 69–78. https://doi.org/10.3141/2664-08

Appendix