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MOBILITY AS A SERVICE (MAAS) IN DEVELOPING COUNTRIES

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Abstract

In face of the continuous trend of urbanization, in combination with tightening environmental targets, transport systems in metropolitan areas are put under great pressure. In response, new mobility concepts have been introduced in recent years. In particular, Mobility as a Service (MaaS), which promotes a shift from private cars towards mobility being consumed as a service, gained a strong momentum. First insights from case studies on MaaS schemes and trials suggest that it enables a shift towards more sustainable transport modes. With MaaS being concentrated mostly in Europe, this PhD project explores MaaS' potential in developing countries. The research, thereby, includes a view from the demand as well as the supply side and intends to quantify potential benefits.

We first aimed to find evidence for the expected diffusion of MaaS in developing countries. In this context, we have studied international diffusion patterns of New Mobility Services (NMS) via internationalization of mobility start-ups. We show that NMS typically spring from developed lead markets (e.g., the USA and Europe) and from there diffuse globally including into the developing world, through market leader expansion or imitation. At the same time, it has been found that mobility start-ups increasingly aim to offer additional services and thus develop into MaaS providers and that the public sector strongly promotes the provision of integrated transport services. We also show that the corona pandemic has created a window of opportunity for a transition towards MaaS. Based on the results of our Metro Manila case study, we argue that MaaS harbors massive opportunities for the generation and utilization of much needed data – not only for informing time-sensitive decisions for responding to such pandemics, but also for long-term transport planning and strategy building.

During a research visit at the University of the Philippines National Center for Transportation Studies (UP-NCTS), we analyzed the willingness to adopt MaaS through binary probit models. Our results show that the vast majority (84 %) of respondents of an online survey (N=238) would likely use a MaaS app and that the willingness to increase the usage of public transport under MaaS is very high (61 % of the total respondents which corresponds to 73 % of the potential MaaS users). It was found that MaaS can leverage multimodal travel behavior and the increased use of transport apps. The statistical models further indicate that the main reasons for adoption are users' expectations of a cheaper and more reliable service.

In another study, we aimed at identifying how users in Metro Manila can benefit from MaaS. Considering that one of the main components of MaaS relates to transport integration, we calculated how accessibility to transit may change under MaaS. The results indicate that the integration of paratransit (i.e., jeepneys) into the transit network could almost triple accessibility from 23.9 % to 65.0 %. The integration of micro-mobility (i.e., e-scooter and bicycles) as a feeder mode could further boost this share significantly (to 97.9 % and 99.9 %, respectively). This suggests that under MaaS, areas that are underserved by public transport could be connected to the transit network, which is a promising way to address latent demand and compensate for lacking transport infrastructure.

This research work also sheds light on MaaS governance issues in global South context. Through a literature review and a two-round international expert survey, we identified a set of implementation barriers for MaaS in developing countries. We categorized these barriers according to the technology-organization-environment (TOE) framework and the experts assessed the relevance of these barriers on a 5-point Likert scale. Based on the results, developing cities capabilities to establish MaaS and other transport innovations are discussed.

In conclusion, this research project unfolds the existing demand for MaaS and highlights that MaaS is likely to gain traction in the global South, especially in dense urban areas. It identifies potential users and how they could benefit from an integrated transport system under MaaS. Furthermore, this work provides a comprehensive discussion on required policies and points out promising lines of future research.

This PhD project has produced five peer-reviewed publications, while additional papers are currently under review. The work associated with this project has been presented at four international conferences (e.g., EWGT and ITS world congress) and three national conferences, and received recognitions from international organizations such as ITF/OECD and UITP.

Keywords: Mobility as a Service (MaaS), Transport Innovation, Integrated Transport, Sustainable Mobility, Transport Policy, Global South.

Resumo

Diante da contínua tendência de urbanização, combinada com metas ambientais cada vez mais rígidas, os sistemas de transporte nas áreas metropolitanas estão sobre grande pressão. Em resposta, novos conceitos de mobilidade foram introduzidos nos últimos anos. Em particular, a Mobilidade como Serviço (MaaS), que promove a mudança da posse e utilização do transporte individual para uma mobilidade consumida como um serviço, tem ganho uma importância crescente. O conhecimento resultante dos estudos de caso sobre as primeiras implementações de esquemas MaaS sugere que a MaaS permite uma mudança para modos de transporte mais sustentáveis. Com os esquemas MaaS localizados principalmente na Europa, esta dissertação explora o potencial da MaaS em países em desenvolvimento. O trabalho de investigação aborda quer o lado da procura quer o lado da oferta e pretende quantificar os potenciais benefícios.

O primeiro objetivo foi encontrar evidências sobre a potencial difusão de MaaS em países em desenvolvimento. Neste contexto, estudaram-se os padrões de difusão internacional de Novos Serviços de Mobilidade (NMS) via internacionalização de startups de mobilidade. Mostrou-se que os NMS normalmente surgem em mercados líderes (por exemplo, Estados Unidos da América ou Europa) e de lá se difundem globalmente, incluindo os países em desenvolvimento, através da expansão do líder de mercado ou de imitação. Em paralelo, verificou-se que as startups de mobilidade visam cada vez mais aumentar a sua oferta com serviços adicionais de transporte e, assim, transformarem-se em fornecedores de serviços de MaaS e que o setor público promove fortemente a integração de serviços de transporte. Também se mostrou que a pandemia da covid-19 criou uma janela de oportunidade para uma transição para a MaaS. Com base nos resultados do nosso estudo de caso na área metropolitana de Manila, argumentamos que a MaaS proporciona enormes oportunidades para a geração e utilização de dados essenciais – não apenas para suportar decisões atempadas para responder a pandemias, mas também para o planeamento estratégico de transportes, a longo prazo.

Durante uma estadia para investigação no Centro Nacional de Estudos de Transporte da Universidade das Filipinas (UP-NCTS), analisamos a propensão dos utilizadores para adotar a MaaS, através de modelos probit binários. Os resultados mostram que a maioria (84 %) dos entrevistados de um inquérito online (N=238) provavelmente usaria um aplicativo MaaS e que a inclinação para aumentar o uso de transporte público sob MaaS é muito alta (61 % do total de respondentes, o que corresponde a 73 % dos potenciais utilizadores de MaaS). Verificou-se que a introdução de MaaS poderá beneficiar com o atual comportamento multimodal dos utilizadores e com o crescente uso de

aplicações móveis de transporte. Os modelos estatísticos indicam ainda que os principais motivos de adoção são as expectativas dos usuários de um serviço mais barato e mais confiável.

Num outro estudo, pretendemos identificar como é que os utilizadores da área metropolitana de Manila poderão beneficiar da implementação de MaaS. Considerando que uma das principais caracterísitcas da MaaS diz respeito à integração de transportes, calculamos como a acessibilidade ao transporte público pode mudar com a MaaS. Os resultados indicam que a integração dos transportes informais (por exemplo, jeepneys) na rede de transportes poderia quase triplicar a acessibilidade (de 23,9 % para 65,0 %). A integração da micromobilidade (como trotinetas e bicicletas) como um modo "alimentador" da rede, poderia aumentar ainda mais o acesso (para 97,9 % e 99,9 %, respetivamente). Isto sugere que, com a MaaS, áreas que não são atualmente cobertas pelo transporte público poderão ser conectadas à rede de transportes públicos, o que é uma maneira promissora de responder à procura latente e compensar a falta de infraestruturas e serviços de transporte.

Este trabalho de pesquisa também incide sobre questões de governança da MaaS no contexto do Sul global. Através de uma revisão da literatura e de um inquérito com especialistas internacionais, em duas rondas, identificamos um conjunto de barreiras à implementação de MaaS em países em desenvolvimento. Categorizamos essas barreiras de acordo com o modelo TOE e os especialistas avaliaram a relevância dessas barreiras através de uma escala Likert de 5 pontos. Com base nesses resultados, discute-se a capacidade deste tipo de cidades para implementar a MaaS e outras inovações de transporte.

Em conclusão, este trabalho de investigação explora a procura existente por MaaS e assinala que a MaaS provavelmente ganhará força no Sul global, especialmente em áreas urbanas densas. Identifica as características dos utilizadores potenciais e como estes poderão beneficiar com um sistema integrado de transportes sob um esquema MaaS. Além disso, fornece uma discussão abrangente sobre as políticas necessárias para a sua implementação e aponta linhas para investigação futura.

No âmbito desta dissertação foram já publicados quatro artigos em revistas científicas peer-reviewed, estando outros artigos atualmente em revisão. Os diferentes trabalhos foram apresentados em quatro congressos internacionais (por exemplo, EWGT e ITS World Congress), três congressos nacionais. Por último, salienta-se o reconhecimento recebido de organizações internacionais como ITF/OCDE e UITP.

Palavras-chave: Mobilidade como Serviço (MaaS), Inovação em Transportes, Integração de Transportes, Mobilidade Sustentável, Políticas de Transporte, Países em desenvolvimento.

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Abbreviations

AMOC	At most one change
BGC	Bonifacio Global City
BM	Business model
BRT	Bus rapid transit
CBD	Central business district
CoastalDEM	Coastal digital elevation model
DOHRP	Department of Health - Republic of the Philippines
DOTr	Department of Transportation
DPWH	Department of Public Works and Highways
ECQ	Enhanced community quarantine
EDSA	Epifanio de los Santos Avenue
eVAP	Electric Vehicle Association of the Philippines
GCQ	General community quarantine
GHG	Greenhouse gas
GTFS	General Transit Feed Specification
HOV lane	high-occupancy vehicle lane
IATF-EID	Inter-Agency Task Force for the Management of Emerging Infectious Diseases
IRR	Implementing Rules and Regulations
ISM	Interpretive structural modeling
LTFRB	Land Transport Franchising and Regulatory Board
LTO	Land Transportation Office
LRT	Light rail transit
MaaS	Mobility as a Service
MECQ	Modified enhanced community quarantine
MM	Metro Manila
MMDA	Metropolitan Manila Development Authority
MRT	Mass Rapid Transit
NMS	New Mobility Services
NTP	National Transport Policy
OSM	OpenStreetMap
PUVMP	Public Utility Vehicle Modernization Program
PSA	Philippine Statistics Authority
SD	Standard Deviation
TNC	Transport Network Companies
TOE framework	Technology-organization-environment framework
UP-NCTS	University of the Philippines - National Center for Transportation Studies
UVVRP	Unified Vehicular Volume Reduction Program
VMT	Vehicle-miles traveled
WHO	World Health Organization
WTP	Willingness to pay
XaaS	Everything as a Service

Mobility as a Service (MaaS) in Developing Countries

Chapter 1

1. Introduction

1.1. Background and motivation

Transport plays an important part in modern societies and is a pivotal factor for economic growth. At the same time, however, it is inextricably linked to negative externalities such as traffic congestion, accidents, and air and noise pollution. Public authorities and policymakers thus frequently account transport-related problems as one of their key responsibilities (Lyons, 2004). Consequently, they advocate for shifts towards more sustainable modes of transport, reducing dependency on private cars, and decarbonizing the transport sector, among others (e.g., Banister, 2011; Nakamura and Hayashi, 2013; Pojani and Stead, 2018).

These objectives are of particular relevance in the context of urban areas, which are characterized by high population size and density. Most of the world's highest and most densely populated cities and metropolitan areas are thereby found in the global South (Table 1.1). Opposed to many cities in the global North (e.g., Tokyo and Osaka in Japan), the so-called megacities (i.e., populations of 10M and more) in developing countries often continue to experience fast population growth.

Table 1.1. Most populous metropolitan areas in the world

Metropolitan Area, Country	2022 Population	2021 Population	Change in %
Tokyo, Japan	37,435,191	37,339,804	–0.18
Delhi, India	32,065,760	31,181,376	2.84
Shanghai, China	28,516,904	27,795,702	2.59
Dhaka, Bangladesh	22,478,116	21,741,090	3.39
Sao Paulo, Brazil	22,429,800	22,237,472	0.86
Mexico City, Mexico	22,085,140	21,918,936	0.76
Cairo, Egypt	21,750,020	21,322,750	2.00
Beijing, China	21,333,332	20,896,820	2.09
Mumbai, India	20,961,472	20,667,656	1.42
Osaka, Japan	19,059,856	19,110,616	–0.27

Italic marks metropolitan areas in the global South

(Source: https://worldpopulationreview.com/world-cities)

It is thus not surprising that, in many cases, developing cities are facing more drastic problems related to transport compared to cities in developed countries (Cervero, 2013; Pojani and Stead, 2018), whereas rapidly declining mobility and accessibility are among the most severe consequences. In other words, this means that travel times are usually extremely high and increasing, while the number of accessible destinations during a given time is decreasing (Dimitriou and Gakenheimer, 2011). The most frequent contributors for such conditions, according to Dimitriou and Gakenheimer (2011), are the rapid pace of motorization, the incompatibility of urban structure, and local demand that far exceeds the capacity of transport systems.

The strategy arranged by development aid agencies such as the World Bank to address these issues usually encompass transport infrastructure projects with the intention to increase the capacities of transport systems. Recent projects being financed by the World Bank, for instance, include the Quito Metro Line One Project in Ecuador and the bus rapid transit (BRT) system in Dakar, Senegal (World Bank, n.d.). However, even assuming that these projects would deliver remarkable results, what they have in common is that they are long-term projects that may take up to several years to complete. In addition to any of such long-term infrastructure projects, complementary projects that increase overall efficiency and could enable short-term results should be established as well.

With regards to the latter, the transport sector has recently experienced the emergence of transport innovations that, among others, draw on societal changes and the integration of new technologies (e.g., Cassetta et al., 2017; Kamargianni et al., 2016). Within the course of this progress, innovative mobility solutions (e.g., carpooling, ride-hailing, and car-, bicycle-, and e-scooter sharing) have been introduced and new start-up companies formed, which in a relatively short time gained considerable attention and created significant improvements.

Eventually, this development has paved the way for Mobility as a Service (MaaS), a new mobility concept that is seen as a solution to support alternatives to the private car. The MaaS model intends to offer integrated mobility services that are accessible on demand and through a single interface, by combining public and private transport modes, in order to serve individual mobility needs (Utriainen and Pöllänen, 2017).

A MaaS scheme is expected to increase the efficiency of a transport network and improve the performance of the integrated services (Becker et al., 2020), while being able to offer seamless customer experience across all transport modes (Jittrapirom et al., 2017). As a result, MaaS is often considered as an opportunity to loosen people’s reliance on private cars (Jittrapirom et al., 2017) and thus counteract the car-centric development of the past decades in many parts of the world.

In the global North, first large-scale MaaS schemes such as *Whim* in Helsinki or *Jelbi* in Berlin are showing promising results, encouraging emulation in other parts of the world. Indeed, MaaS has recently also aroused interest in the developing world and is seen as a solution to mitigate existing transport problems (Moody and Bianchi Alves, 2022). However, while an overview of the MaaS-Alliance shows a strong concentration of MaaS schemes in the global North (Figure 1.1), MaaS is still in its infancy in the global South. The few initiatives in the developing world include a preliminary MaaS scheme in India (Singh, 2020) as well as the EU-funded SOLUTIONSplus project, which involves several MaaS pilots in different cities in Latin America, Africa, and Asia (Panagakos et al., 2023).

Figure 1.1. Global MaaS penetration: Map of cities with existing MaaS schemes or pilots

(Source: MaaS-Alliance; cited in Hasselwander, 2019)

Contemporaneously, academic research on MaaS has virtually only focused on developed countries – whereby studies in the context of Finland (e.g., Audouin and Finger, 2018; Smith et al., 2019), Sweden (e.g., Karlsson et al., 2016; Sochor et al., 2016), Germany (e.g., Hasselwander et al., 2019; Schikofsky et al., 2020), the Netherlands (e.g., Alonso-González et al., 2020; Fioreze et al., 2019), the UK (e.g., Ho et al., 2019; Matyas and Kamargianni, 2019), and Australia (e.g., Ho et al., 2018; Mulley et al., 2020) are dominating. Hence, at the time this PhD project started in 2018, there was a significant knowledge gap – both from theoretical and practical perspective – about what MaaS could mean for the global South. Hence, the present work aims to fill this gap and provide insights for policymakers and transport planners on how to implement MaaS. Note that while we claim to arrive at generalized results for developing countries, in some chapters we use Metro Manila (MM) – a characteristic developing city that encounters many of the aforementioned transport problems – as a case study for data collection and analysis purposes.

The motivation for this research is explained by personal experiences and encounters with transport problems in developing countries and especially in Southeast Asia. The author experienced first-hand – for example, in the Philippines – how (the lack of) transport can negatively affect people's daily routines and limit their mobility (Figure 1.2). In cities such as MM, commuting is therefore often perceived as a burden and can tremendously impair the quality of people's life. The author hopes that the findings of this research will make a humble contribution to ease these transport woes.

Figure 1.2. Commuters' daily struggle to access public transport services in Metro Manila

(Source: John Javellana/Reuters, August 2016 [top]; Ben Nabong/Rappler, March 2020 [bottom])

1.2. Outline and research objectives

This dissertation is organized in 7 chapters (Figure 1.3). Chapter 1 starts with an introduction to the research topic, followed by the main body of this work (Chapters 2-6), and a concluding chapter (Chapter 7).

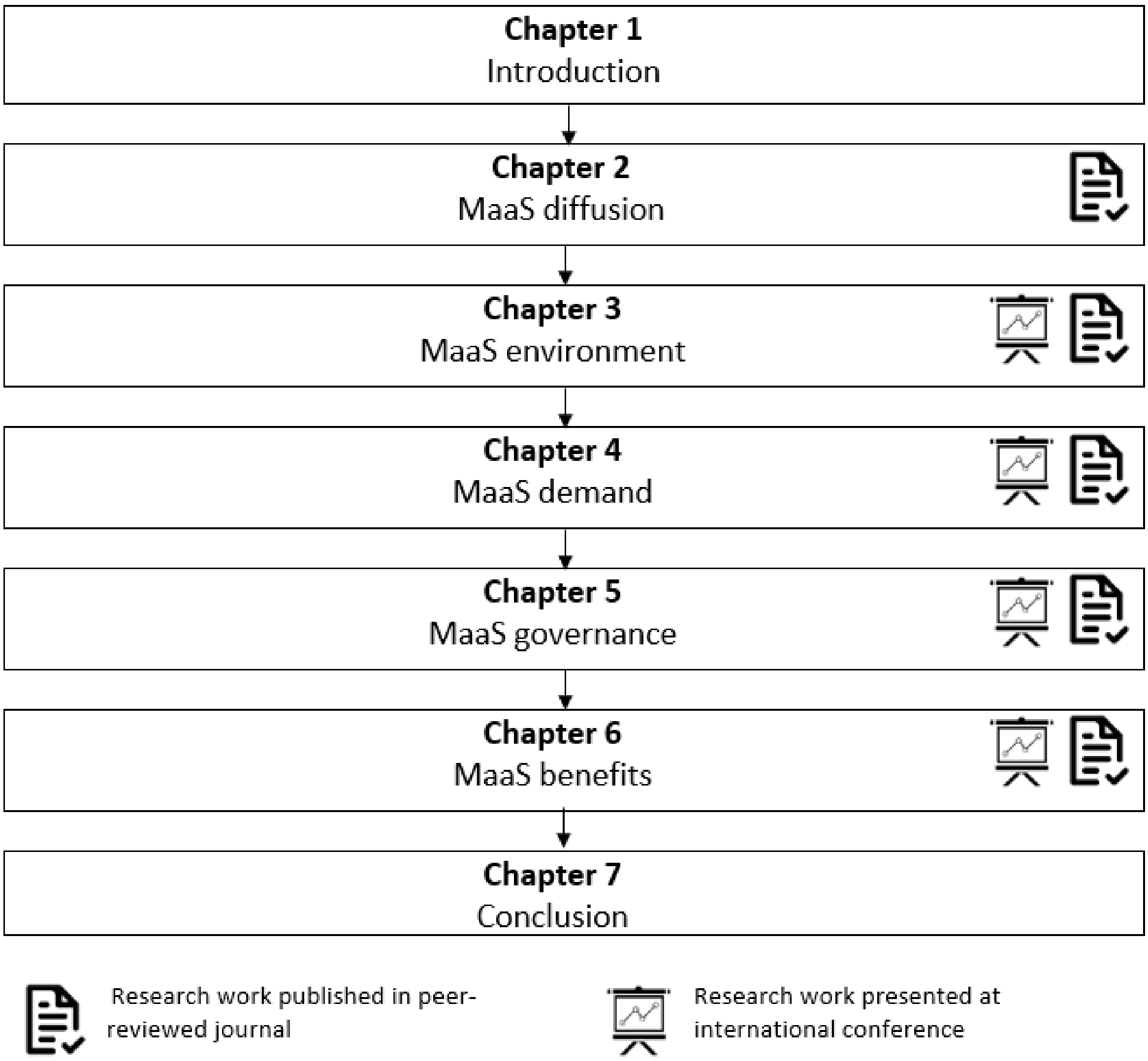

Figure 1.3. Outline of the PhD thesis

The main body of this work is devoted to the following overarching research question:

Is Mobility as a Service (MaaS) a suitable solution to tackle existing transport problems in developing countries?

In each of the chapters in the main body, we forward consecutive research objectives that – in conjunction – aim at answering the above research question.

Below we describe the main body including the respective objectives in each of the chapters in more detail.

- The objective of Chapters 2 and 3 is to find evidence for the diffusion of the MaaS concept in the global South. These chapters can be considered as the foundation of this research project, justifying the further investigation in the subsequent chapters.
  - In **Chapter 2**, we first look into the private sector. We recognize that VC-backed start-ups are the main drivers of new mobility solutions in the emerging mobility ecosystem. Hence, we hypothesize that these companies are also responsible for the global diffusion of the concept. By understanding mobility start-ups' internationalization patterns from a firm perspective, this chapter aims to outline possible diffusion patterns of MaaS (and other forthcoming mobility solutions) into the developing world.
  - In **Chapter 3**, we analyze how the COVID-19 pandemic has changed mobility behavior in MM and how this can affect the uptake of MaaS. We aim to show that the pandemic has opened a window of political opportunity and created a hotbed for MaaS, in which also the public sector can be a driving force to establish MaaS.
- In Chapters 4-6, we take a closer look at possible implications for implementing MaaS in developing countries.
  - **Chapter 4** is devoted to the demand side. We use binary probit models to analyze the willingness to adopt MaaS in MM. Thereby, we aim to understand who the potential MaaS adopters are as well as their motives to use MaaS. Based on stated intentions, we also investigate whether MaaS could promote sustainable mobility behavior and a shift towards more sustainable transport modes.
  - **Chapter 5** is devoted to the supply and governance side. In this chapter, we argue that the public sector should anticipate the implementation of MaaS. Thus, we aim to outline possible barriers that could hamper the implementation of MaaS in developing countries from the point of view of transport authorities. For this purpose, we draw on data that we collected through an international expert survey. We then use the technology-organization-environment (TOE) framework to identify and rank possible barriers, and understand how they relate to each other.
  - The objective of **Chapter 6** is to quantify possible benefits of MaaS in developing countries. Here, we focus on changes in accessibility to transit, which is one of the key indicators to assess the performance of transport systems. In this context, we

introduce a novel approach that leverages open data sources to calculate potential accessibility gains under MaaS in MM.

Note that this work is written as a cumulative dissertation (opposed to a monograph). The chapters 2-6 comprise work that has been published in scientific journals and/or presented at scientific conferences, respectively (as detailed in the following sub-section). These chapters are therefore structured as per scientific journal standard, which may cause some overlapping content and unavoidable repetitions. However, we deliberately followed such an approach for the following reasons. Each of these chapters (i) is peer reviewed, (ii) makes a contribution to the scientific literature, and (iii) represents a self-sufficient piece of work that can be read independently of one another.

1.3. Dissemination and recognition

During the course of the PhD project, the progress and preliminary results were constantly disseminated both in scientific journals and at conferences. The motivation behind this was to receive feedback from scholars and experts in the field as well as to validate the topic and research methods against the state of the art. Overall, the work related to this PhD project has resulted in five publications in international scientific journals (all Scopus, Science Direct, and/or ISI indexed). In addition, the work has been presented at seven scientific conferences (four international and three national conferences), whereas one special interest session at an international conference has been co-organized by the author. The author further received recognitions for the PhD research from international organizations (i.e., the International Transport Forum at the OECD and the International Association of Public Transport [UITP]), which – in our opinion – underlines the policy relevance of this project.

Please see **Fehler! Verweisquelle konnte nicht gefunden werden.** and **Fehler! Verweisquelle konnte nicht gefunden werden.** for the project recognitions. Below follows the complete list of publications and presentations, organized by the respective chapters to which they relate.

Chapter 2

Hasselwander, M., Bigotte, J. F., & Fonseca, M. (2022). Understanding platform internationalisation to predict the diffusion of new mobility services. *Research in Transportation Business & Management*, 43, 100765. https://doi.org/10.1016/j.rtbm.2021.100765

Chapter 3

Hasselwander, M., Tamagusko, T., Bigotte, J. F., Ferreira, A., Mejia, A., & Ferranti, E. J. (2021). Building back better: The COVID-19 pandemic and transport policy implications for a developing megacity. *Sustainable Cities and Society*, 69, 102864. https://doi.org/10.1016/j.scs.2021.102864

Hasselwander, M., Tamagusko, T., Bigotte, J. F., Ferreira, A., Mejia, A., & Ferranti, E. J. (2021, July 2). Building back better: The COVID-19 pandemic and transport policy implications for a developing megacity [Paper presentation]. *13th CITTA Annual Conference on Planning Research: Planning for Human Scale Cities*, Virtual Event.

Chapter 4

Hasselwander, M., Bigotte, J. F., Antunes, A. P., & Sigua, R. G. (2022). Towards sustainable transport in developing countries: Preliminary findings on the demand for mobility-as-a-service (MaaS) in Metro Manila. *Transportation Research Part A: Policy and Practice*, *155*, 501-518. https://doi.org/10.1016/j.tra.2021.11.024

Bigotte, J. F., & Hasselwander, M. (2021, October 11-15). Demand for MaaS in Developing Countries. Preliminary findings from Manila (Philippines). *ITS World Congress*, Hamburg, Germany.

Hasselwander, M., & Bigotte, J. (2020, February 10-11). A binary probit model to estimate demand for mobility as a service (MAAS) in Metro Manila [Paper presentation]. *17th Encontro do Grupo de Estudos em Transportes (GET) Conference*. Unhais da Serra, Portugal.

Co-Organization of Special Interest Session (SIS 57) “MaaS in Developing Countries” at the ITS World Congress, Hamburg, October 11-15, 2021.

Co-Organizer: Sascha Westermann (City of Hamburg)
Moderator: Roelof Hellemans (MaaS Alliance)
Speaker Panel: Joao F. Bigotte (University of Coimbra), Mirko Goletz (German Aerospace Center), Nicole Siggins (Trufi Association), Leonardo Gutierrez (Trufi Association), Paulo Cantillano (Pluservice)

Chapter 5

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., & Bigotte, J. (2021, September 8-10). Transport Authorities and Innovation: Understanding Barriers for MaaS Implementation in the Global South [Paper presentation]. *24th Euro Working Group on Transportation Meeting (EWGT 2021)*, Aveiro, Portugal.

Chapter 6

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(3), 100086.

Hasselwander, M., Nieland, S., Dematera-Contreras, K., & Goletz, M. (2022, May 18-20). MaaS for the masses: Potential transit accessibility gains and required policies under Mobility-as-a-Service. *International Making Cities Livable (IMCL 2022) Conference*. Paris, France.

Other publications and presentations

Hasselwander, M. (2023, September 6–8). Mobility as a Feature (MaaF): Why and how ride sharing platforms have evolved into super apps. *25th Euro Working Group on Transportation Meeting (EWGT 2023)*, Santander, Spain.

Hasselwander, M., & Bigotte, J. F. (2023). Mobility as a Service (MaaS) in the Global South: research findings, gaps, and directions. *European Transport Research Review*, 15, 27.

Hasselwander and Bigotte (2023). Mobility as a Service (MaaS) in developing countries: research findings, gaps, and directions. *16th World Conference on Transport Research (WCTR 2023).* Montréal, Canada.

Goletz, M., & Hasselwander, M. (2023). Clean energy transition in informal transport: modeling drivers' interest to switch to electric vehicles. *16th World Conference on Transport Research (WCTR 2023).* Montréal, Canada.

Hasselwander, M., Kiko, M., & Johnson, T. (2022). Digital civic engagement, open data, and the informal sector: a think piece. *Transportation Research Interdisciplinary Perspectives*, *16*, 100700. https://doi.org/10.1016/j.trip.2022.100700

Panagakos, G., Goletz, M., Hasselwander, M., Mejia, A., Aittoniemi, E., Barfod, M. B., Dhar, S., Munoz Barriga, M. R., Munshi, T., Painuly, J. P., Shrestha, S., Silla, A., Teko, E., Torrao, G., Werland, S., & Dematera-Contreras, K. (2022, November 14-17). E-mobility solutions for urban transportation: User needs across four continents. *Transportation Research Procedia*.

Hasselwander, M., Senyagwa, J., Martin, E., Andrieu, V. M., Goletz, M., & Lah, O. (2022, November 8-10). Vehicle electrification in informal transport. *Urban Transitions 2022*. Sitges, Barcelona, Spain.

Hasselwander, M. (2019). MaaS in Deutschland. *Internationales Verkehrswesen*, *71*(2), 59.

Hasselwander, M. (2018, July 26-27). Practical Guidance on the conducting of researches. *25th Annual Transportation Science Society of the Philippines (TSSP) Conference*. Cagayan de Oro City, Philippines.

Hasselwander, M., & Bigotte, J. (2018, February 20). Innovation in Transportation: A systematic Literature Review. *15th Encontro do Grupo de Estudos em Transportes (GET) Conference*. Fátima, Portugal.

Chapter 2

2. Understanding platform internationalization to predict the diffusion of new mobility services

2.1. Introduction

The transport sector is currently experiencing a major transformation that is being triggered by technological advances and by societal changes (Cassetta et al., 2017). This has led to the improvement of existing (e.g., carpooling, car-sharing, and bike-sharing) and the development of new (e.g., ride-hailing and electric scooter-sharing) mobility solutions – often referred to as new mobility services (NMS). These NMS (Figure *2.1*) are frequently seen as an opportunity to solve many transport's negative externalities such as congestion, and air and noise pollution. Taking advantage of digital technologies and electrification, and with business models relying on the sharing economy, NMS promise to improve both the environmental sustainability and the efficiency of transport systems (Cohen and Kietzmann, 2014).

Therefore, predicting the evolution of NMS is of interest to both policymakers, transport practitioners, and scholars. These NMS are typically being implemented by technology-based start-ups that appear as new market participants in a burgeoning mobility business environment. In fact, the most successful start-ups, which are often backed with enormous venture capital and many times leverage legal gray areas, have achieved instant global recognition and disrupted[1] rigid markets in a relatively short time.

We argue that mobility start-ups take up a leading role in the worldwide diffusion process of NMS since it is through their strategic decisions regarding the expansion of activities to new geographical markets that NMS become available to users (that, subsequently, can choose to adopt the services or

[1] A widely accepted definition for disruptive innovation was coined by Christensen et al. (2015). In this chapter, however, we adopt the expanded definition that – reasoning with an example based on mobility start-ups – has been suggested by Chase (2016). Accordingly, disruptive innovations are processes in which smaller firms successfully challenge incumbent businesses by creating new (e.g., *Zipcar*) or low-end markets (e.g., *FlixBus*) or by leveraging excess capacity (e.g., *Uber*).

not). This fact has not been accounted for in the transport literature so far. Instead, the diffusion of NMS has mainly been studied through user acceptance and adoption embedded in traditional diffusion theories (El Zarwi et al., 2017). While important contributions have been made to understand the reasons behind the uptake of carsharing (Prieto et al., 2017), bike-sharing (e.g., Bakogiannis et al., 2019), ridesharing (e.g., Alemi et al., 2018), MaaS (e.g., Vij et al., 2020), and so forth, these studies did not attempt to understand where these services are (being made) available in the first place.

Therefore, instead of answering the usual 'Who?', 'Why?', and 'How many?' questions at the user-level, this chapter introduces a new approach by addressing the 'When?', 'Where?' and 'How?' questions at firm-level:

- *Where* do mobility start-ups emerge?
- *When* and *where* do they expand to?
- *How* are NMS being introduced into new markets?

We integrate theories from international business research to answer these questions at the firm-level and to outline expansion and internationalization activities. In this research, we narrow our view on mobility start-ups that are based on digital platforms (hereafter: mobility platforms). By understanding the internationalization of mobility platforms, we aim to retrace the different ways NMS diffuse globally and (if any) outline the observed diffusion patterns which will help to predict the uptake of emerging or future NMS.

Following a multiple case study approach, we focus on ride-hailing, carpooling, and MaaS. For each NMS, the respective market leaders (*Uber*, *BlaBlaCar*, *MaaS Global*) as well as the most relevant followers (*Lyft*, *Cabify*, *Bolt*, *Zimride*, *Waze Carpool*, *UbiGo*, etc.) are analyzed.

This chapter makes several, multidisciplinary contributions to academic literature. First and foremost, it provides new findings about the dynamics of the emerging mobility ecosystem. Second, it contributes to existing studies on diffusion of innovations in transport by introducing a firm-level approach and by integrating transport research with theories of international business strategy. Third, while the literature on adoption of NMS mostly comprises articles that focus on single case studies in developed countries (e.g., Alemi et al., 2018; Vij et al., 2020), this research work applies a global perspective considering the global diffusion of NMS in both developed and developing countries. Fourth, it contributes to the nascent state of international business research on digital platforms (Stallkamp and Schotter, 2019) by providing case study results from major mobility start-ups. And fifth, while product innovations (e.g., vehicle technologies) have received a great deal of attention, this chapter focuses on innovation in services which has been widely overlooked in both transport research (Ongkittikul and Geerlings, 2006) and general innovation studies (Wittel et al., 2016).

The remainder of this chapter is organized as follows. In section 2, we provide the theoretical background for this study. Section 3 details the study methods and the selected case studies for each NMS. Section 4 presents a comprehensive examination of the diffusion of NMS. Section 5 discusses the main findings. Finally, we present concluding remarks in Section 6.

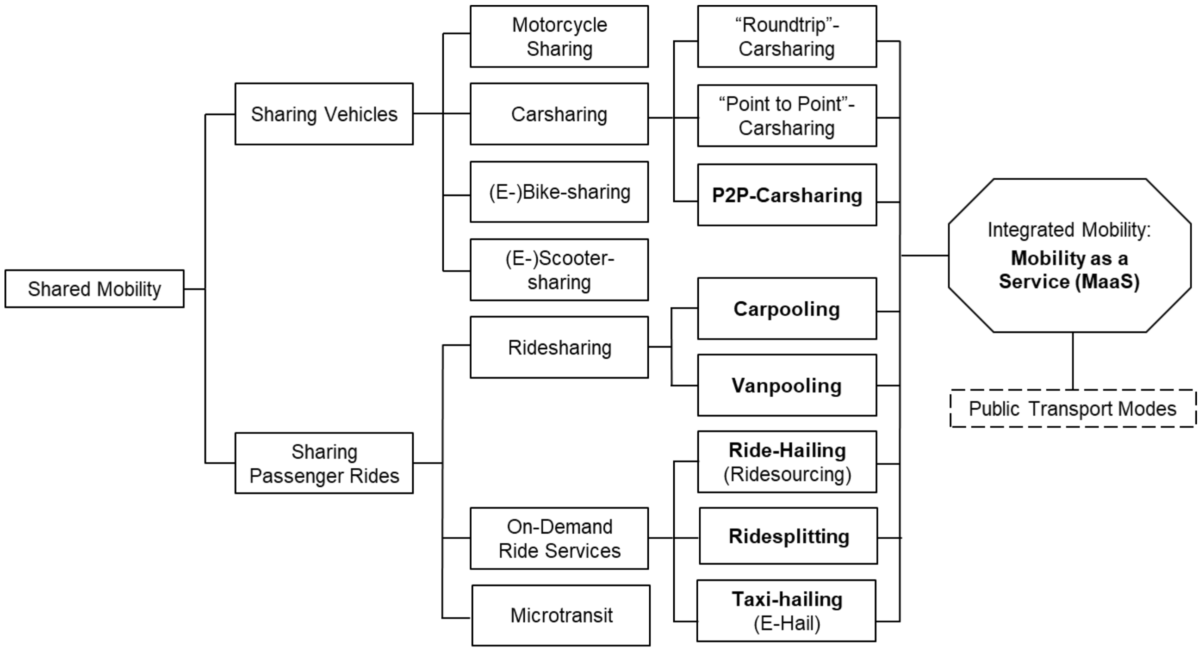

Figure 2.1. New mobility services in the emerging mobility ecosystem
Source: expanded from Shaheen and Chan, 2016

2.2. Background

2.2.1. Innovation and diffusion (in transport)

Innovation is a term that is (still) employed in a rather loose way with diverse definitions in use. In this study, we adopt the OECD definition at firm-level. Accordingly, innovation refers to the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations” (OECD, 2005, p. 46). The diffusion of innovation usually starts in one country or region (the lead market), before diffusing internationally (Beise, 2004). The process is often driven by the innovator (entrepreneur, firm, etc.), who, in competitive global markets, seeks for quick international expansion to benefit from so-called lead effects (Kalish et al., 1995). At the same time, successful innovation calls followers into action who further accelerate the process of diffusion. They either imitate the innovation (imitators or “copycats”) or create, built on the predecessor, successive innovations (sequential innovators) (Bessen and Maskin, 2009).

In the transport literature, innovation and diffusion have been addressed mainly in the context of new transport technologies (e.g., Costa and Fernandes, 2012; Sousa et al., 2020). However, innovation in transport is not only expected through the integration of new technologies, but also through innovative mobility services and the development of new concepts of mobility (Cassetta et al., 2017). Most NMS spring from the developed world, where they are frequently anticipated as possible measures to loosen people’s reliance on private cars and to increase the efficiency and sustainability of the overall transport system.

In developing countries, in contrast, lower technological capabilities and reduced financial resources for R&D result in lower involvement in innovation activities (Da Silveira, 2001). Notwithstanding, pioneering cities from the global South (e.g., Bogotá and Curitiba) have successfully demonstrated the introduction of low-cost transport innovations such as the BRT (OECD/ITF, 2019). Scientific literature, however, has not acknowledged the actual relevance and potential of transport innovations in developing countries and rarely addressed adoption and diffusion of NMS in its context (Acheampong et al., 2020).

2.2.2. Sharing economy and the platform business model

The sharing economy, also referred to as collaborative consumption, is an important concept to understand recent developments in the mobility ecosystem. Despite being widely acclaimed, however, a common approach for the conceptualization of the sharing economy has yet to be developed. Cockayne (2016), for example, uses the term to summarize digital platforms that connect consumers to a service or commodity through mobile apps or websites. These platforms create value by promoting and facilitating transactions between different types of users (Evans and Gawer, 2016). Compared to long-established solutions, platforms typically provide improvements such as on-demand availability, efficiency, and convenience (Still et al., 2017). An important characteristic of platforms is the creation of two-sided markets, where different user segments can interact with each other. The more users a platform has on each side, the greater are the benefits for all participants of the platform. This relation is also referred to as network effects (Parker and Van Alstyne, 2005).

In the context of this chapter, it is worth considering platforms from the perspective of the business model concept and thus relating to the Platform Business Model (Osterwalder and Pigneur, 2010). Scholars describe a business model (BM) as the 'logic of the firm' (Casadesus-Masanell and Ricart, 2010). It defines how a business creates and delivers value to customers and outlines the firm's architecture of revenues, costs, and profits (Teece, 2010). The BM inevitably demonstrates the firm's performance to the external environment. In response, it may thus serve as a template and potentially may call for imitation.

While a great amount of attention has been attributed to the idea of novelty creation through BM innovation, the replication of BMs has been widely overlooked in the scientific literature (Aspara et al., 2010). Yet, refining existing BMs for replication into new geographical locations signifies a promising strategy to maintain growth and maximize value (Winter and Szulanski, 2001). This requires recognizing the valuable traits of the BM, knowing how these traits can be replicated, and identifying suitable locations where solutions with such traits can be successfully implemented (Winter and Szulanski, 2001).

Scalability is another decisive attribute of BMs relating to its function to contribute to the growth of a firm. In other words, scalable BMs are able to increase revenues from additional resources faster than the underlying cost base (Stampfl et al., 2013). Digital platforms have high scaling potential if they can continuously gain users on both sides at a marginal cost for additional transactions close to zero (Täuscher and Kietzmann, 2017). This can be achieved by delivering higher value propositions relative to existing alternatives (Lund and Nielsen, 2018) while reducing transaction costs and/or enhancing the efficiency of matching (Brousseau and Penard, 2007).

2.2.3. Internationalization of digital platforms

While the concept of diffusion relates to the innovation (e.g., a NMS), the concept of international expansion – or internationalization – relates to the firm and describes the process in which a firm (e.g., a mobility service provider) increases its international involvement. Internationalization of firms can be achieved through different options, including exports, licensing, and foreign direct investment. In this chapter, the latter way of international expansion is of particular interest, as it involves two main options: setting up start-ups from scratch or acquiring foreign ventures (Barkema et al., 1998).

Classical theory (Johanson and Vahlne, 1977) claims that internationalization is the product of a series of incremental decisions in which knowledge about foreign markets and foreign market commitment are gradually increasing over time. Hence, firms increase their activities abroad gradually (gradual internationalization). Due to their nature of intangible assets, however, digital platforms can potentially adapt rapidly into different markets at lower costs (rapid internationalization) (Parente et al., 2018). One of the influential forces that determine the speed of internationalization, according to Oviatt and McDougall (2005), is the motivating force of competition. Technology-based firms are particularly impacted by global competition (Onetti et al., 2012), which is why many digital platforms aim for internationalization near to inception. Hereby, leveraging on first-mover advantages is seen as a critical factor to gain competitive advantages (Parente et al., 2018).

Once first activities have been established abroad, the pace of internationalization is further determined by the expansion strategy. Logically, an approach in which many markets are targeted for entry at the same time (sprinkler strategy), allows to expand much faster than targeting new markets successively (waterfall strategy) (Kalish et al., 1995). With regards to market selection, one option is to target a diverse set of country markets in different geographical locations (geographical diversification). In contrast, geographical concentration refers to the case, where firms try to achieve market share only in selected markets in close geographic proximity (Ayal and Zif, 1979).

Stallkamp and Schotter (2019) found that the geographic scope of network effects (*within-country* or *cross-country*) further influences digital platforms' key internationalization decisions. An important finding is that global strategies are more likely to be pursued by digital platforms creating network effects that extend across borders.

An internationalization model for digital platforms has been developed by Ojala et al. (2018). It considers four stages that digital platforms follow in their path towards globalization (Figure *2.2*). After inception, in the *Establishment* phase, platforms start to look for ways to commercialize internationally. *Early internationalization* is as a case-dependent intermediate step to overcome technical/strategic bottlenecks (e.g., legal provisions that prevent carriage of passengers by unregulated NMS such as ride-hailing and carpooling) or to acquire necessary resources. In this phase, the platform is only capable of entering selected markets, in which no obstacles exist and where potentially missing resources are obtainable. The next phase is the *Commercialization*, in which platforms aim for customer bases in larger markets. Finally, in the *Globalization* phase, the platform is expected to be mature and globally accepted.

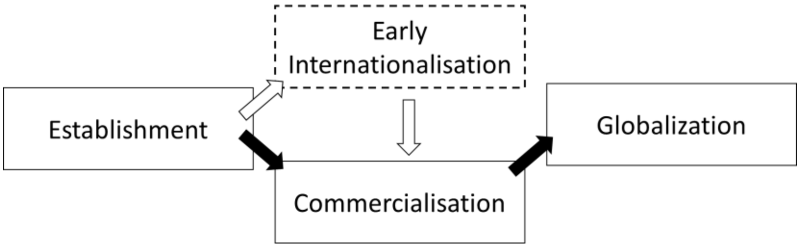

Figure 2.2. Internationalization model for digital platforms

Source: adapted from Ojala et al., 2018

2.3. Methodology

Building on the concepts and theories described in the background section, we advance the following propositions to address our research objective:

- **Proposition 1**: The rapid or gradual internationalization of firms (i.e., mobility platforms) reported in the literature, determine rapid or gradual diffusion of innovations (i.e., NMS).
- **Proposition 2**: Whether mobility platforms follow a rapid or gradual internationalization is influenced by various (inter-related) factors including (a) the BM, (b) network effects, (c) competition, and (d) the expansion strategy (Table *2.1*).

For our analysis, we follow a multiple case study approach. Compared to a single case study, this allows to obtain more compelling evidence and more in-depth understanding, therefore being considered as more robust (Eisenhardt and Graebner, 2007). Yamashita and Moonen (2014), nevertheless, refer to case selection bias as the biggest challenge of this research method.

We analyze one NMS for each of the stages in the internationalization model for digital platforms (Ojala et al., 2018), only excluding the first stage (establishment in the lead market) in which internationalization efforts are yet to be observed. Following a purposive sampling approach, we select MaaS, carpooling, and ride-hailing for the early internationalization, commercialization, and globalization stage, respectively. We consider these as the most instructive cases, as they represent NMS that have attracted much interest from the private sector (read off by the raised venture capital funding of each) and that are well-studied in the scientific literature. Our analysis starts with the market leaders – *Uber* (ride-hailing), *BlaBlaCar* (carpooling), *MaaS Global* (MaaS). Expecting that more successful solutions call for increased imitation, we further analyze the most relevant followers, that are either imitators and/or sequential innovators (Table *2.2*).

Table 2.1. Overview of explanatory variables for the case analyses

	Variable	Classification	Reference
	Business model		
a1	-Replicability	low/medium/high	Winter and Szulanski, 2001
a2	-Scalability	low/medium/high	Brousseau and Penard, 2007; Lund and Nielsen, 2018; Täuscher and Kietzmann, 2017
	Network effects		
b1	-Geographic scope	within-country/cross-country	Stallkamp and Schotter, 2019
	Competition		
c1	-Geographic scope	local/regional/international	Onetti et al., 2012; Oviatt and McDougall, 2005; Parente et al.,
c2	-Intensity	low/medium/high	2018
	Expansion strategy		
d1	-Market selection	geographical diversification/ geographical concentration	Ayal and Zif, 1979
d2	-Market entry	sprinkler/waterfall	Kalish et al., 1995

Table 2.2. Overview of case studies

Case	NMS	Internationalization Stage	Market Leader	Imitators and Sequential Innovators
I	Ride-Hailing	Globalization	*Uber*	*Lyft*, *Cabify*, *Bolt*, *Didi Chuxing*, *Grab*
II	Carpooling	Commercialization	*BlaBlaCar*	*Zimride*, *Waze Carpool*, *Wunder Mobility*
III	Mobility as a Service (MaaS)	Early Internationalization	*MaaS Global*	*UbiGo*, *Free2Move*, *moovel*, etc.

The data for this study has been collected from available primary literature and a web search relying on various online sources (organizations' official online channels, press releases, blog posts, industry reports, local newspaper articles, published interviews with representatives, etc.). We are confident that the data collection, being conducted in an unobtrusive, exhaustive manner, yields a close representation to reality. However, even though available data from online sources help to avoid selection bias by data providers (Edelman, 2012), some doubts regarding accuracy and reliability of such data naturally remain. Note that the mobility ecosystem is affected by strong market dynamics. We therefore need to mention that the information cut-off for our data is October 2019, and that some information may not be valid anymore by the time of publication.

With regards to the origin of start-ups and where they expand, our analysis includes a distinction between developed countries and developing countries which is relevant in the context of both transport and international business studies. Based on World Bank data, we consider countries listed in the group of high-income economies as developed countries and the remaining as developing countries (World Bank, 2020a).

2.4. Diffusion of new mobility services

2.4.1. Ride-hailing (globalization stage)

Ride-hailing, also referred to as ridesourcing, describes a point-to-point on-demand mobility service, in which passengers hail drivers via mobile apps (Jin et al., 2018). The passengers and drivers connect on online-enabled platforms that are operated by ride-hailing companies, also called Transport Network Companies, TNCs (Jin et al., 2018). A distinctive feature is that the TNC does not own the vehicles itself, instead, vehicles are owned by the supplier (a company or an individual). The main reasons for passengers to use ride-hailing services have been identified as low prices and convenience (to book rides online, to use the same app in different cities/countries), as well as short waiting times (Rayle et al., 2016). Despite creating huge controversies and immense protest from the taxi industry, in many cases resulting in legal battles, ride-hailing services have become a global phenomenon being operated in many parts of the world (Table *2.3*).

Table 2.3. Evolution of ride-hailing services: First launch in selected cities

Innovation	Diffusion in Developed Countries	Diffusion in Developing Countries
San Francisco (July 2010)	New York City (May 2011)	Santiago de Chile (November 2012)*
	Paris (December 2011)	Mexico City (January 2013)*
	Madrid (January 2012)*	Bangalore (August 2013)
	*Barcelona (February 2012)**	Johannesburg (August 2013)
	Toronto (March 2012)	Bogotá (September 2013)
	London (July 2012)	Kuala Lumpur (January 2014)

	Sydney (November 2012)	Manila (February 2014)
	Singapore (January 2013)	Rio de Janeiro (April 2014)
	Berlin (February 2013)	Beirut (July 2014)
	Rome (May 2013)	Beijing (July 2014)
	Seoul (June 2013)	Bangkok (October 2014)
	Dubai (September 2013)	Colombo (December 2015)
	Tokyo (November 2013)	Lagos (July 2014)
	Moscow (November 2013)	Cairo (November 2014)
	Doha (January 2014)	Nairobi (January 2015)
	Brussels (February 2014)	Minsk (November 2015)
	Lisbon (July 2014)	Baghdad (January 2018)*

Asterisk marks locations where ride-hailing services have first been introduced by followers
Italic marks locations where ride-hailing services are banned or significantly restricted (as of June 2019)

2.4.1.1. Uber (market leader)

A major role in the rapid development of ride-hailing is played by *Uber*. Founded in March 2009, *Uber* first introduced ride-hailing services in San Francisco, USA, in 2010. Meanwhile, *Uber* offers several transport-related services under brands such as *UberTaxi*, *UberPool*, and *Jump*. With *Uber Eats*, the portfolio even includes a meal delivery service. The core and most important service, however, remains ride-hailing. Although *Uber* initially operated in a legal gray area and despite opposition from the taxi industry, users highly demanded for *Uber*'s services. While continuously raising capital, *Uber* has sought to expand and offer services in more cities. The company's national expansion began in May 2011 with the launch in New York City. Since then, *Uber* has experienced rapid growth – both nationally and internationally. For insights regarding *Uber*'s expansion patterns in the USA, the reader is referred to Berger et al. (2018) and Hall et al. (2018). The first step of *Uber*'s international expansion marks the launch in Paris, France, in December 2011. First imitators have been founded in 2012 and onwards, emerging in both the developed and the developing world (Figure *2.3*). In many cases, however, they initially offered taxi-hailing services before focusing on ride-hailing.

Uber's international expansion first included cities in Europe, Canada, and Australia, before starting to launch in developing countries. *Uber* arrived in Mexico City in June 2013, six months after the imitator *Cabify* had launched in the city. Since August 2016, according to the collected data, *Uber* offers ride-hailing services (labeled as UberBlack for the premium service and *UberX*, *UberXL*, or *UberPop* for cheaper services) in more developing countries than in developed countries. In total, it has launched in 77 different countries, but in some was forced to withdraw. In developed countries mainly due to legal constraints such as bans and restrictions imposed by local authorities (e.g., in Germany, Denmark, and South Korea). In developing countries, where typically fewer regulatory issues can be expected, *Uber*, in a few cases, withdrew from operations and partnered with strong local competitors (e.g., *Didi Chuxing* in China and *Grab* in Southeast Asia). With the acquisition of Dubai-based *Careem* in March 2019, another major competitor has been taken over. *Careem*, however, keeps operating separately and under the old brand in the Middle East, Africa, and South Asia.

As could be expected, a scatter plot (R^2=0.32) of *Uber*'s entry in European cities shows a negative correlation of the city's population size and the respective launching date (Figure *2.4*). This means that *Uber* first launched in cities with relatively high populations, before launching in lower populated cities. The same has been observed in the US market (Berger et al. 2018; Hall et al., 2018), which supports the general assumption that digital platforms rely on widespread user adoption and therefore target regions with dense urban populations. It further reveals that the expansion started in Western European countries (France, UK, Netherlands, Germany, Italy, etc.), before *Uber* also began targeting cities in Eastern Europe (e.g., in Russia, Romania, Poland, Ukraine, etc.). The most recent launches mainly include relatively small cities in Western Europe (e.g., Coimbra or Graz) as well as cities where *Uber* has faced strong opposition (e.g., Cologne or Seville).

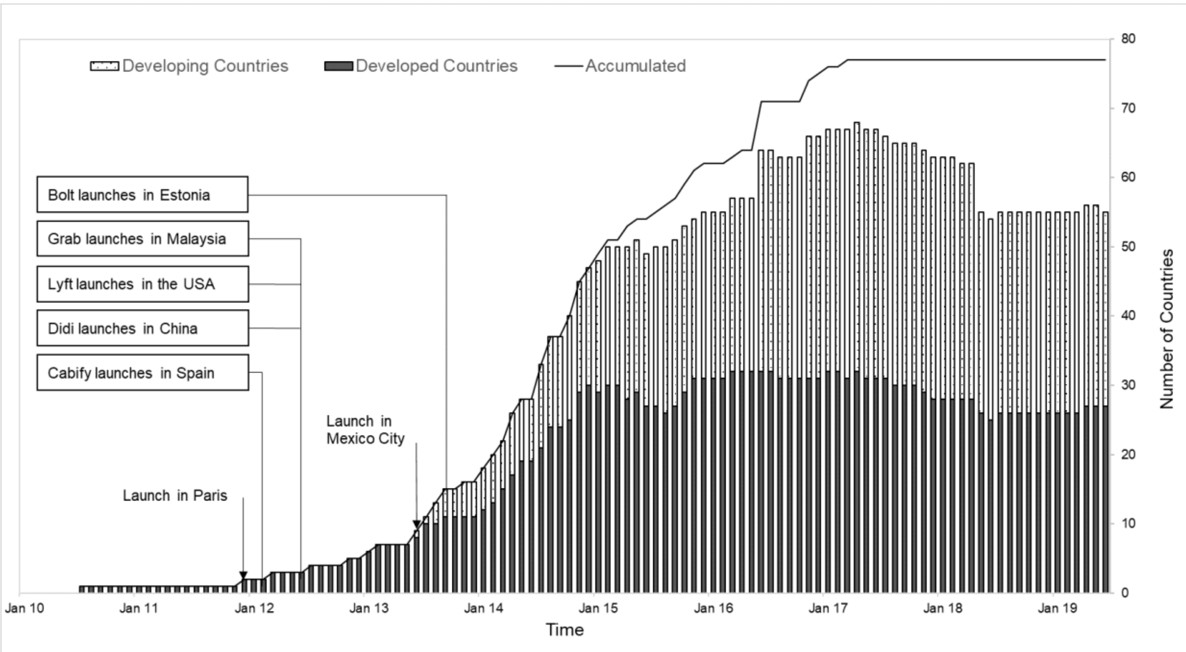

Figure 2.3. Expansion of Uber and launch of major competitors

Note: The accumulated line represents the total sum of countries in which Uber has launched ride-hailing services over time, while the bars refer to the number of countries in which Uber was active at a given time.

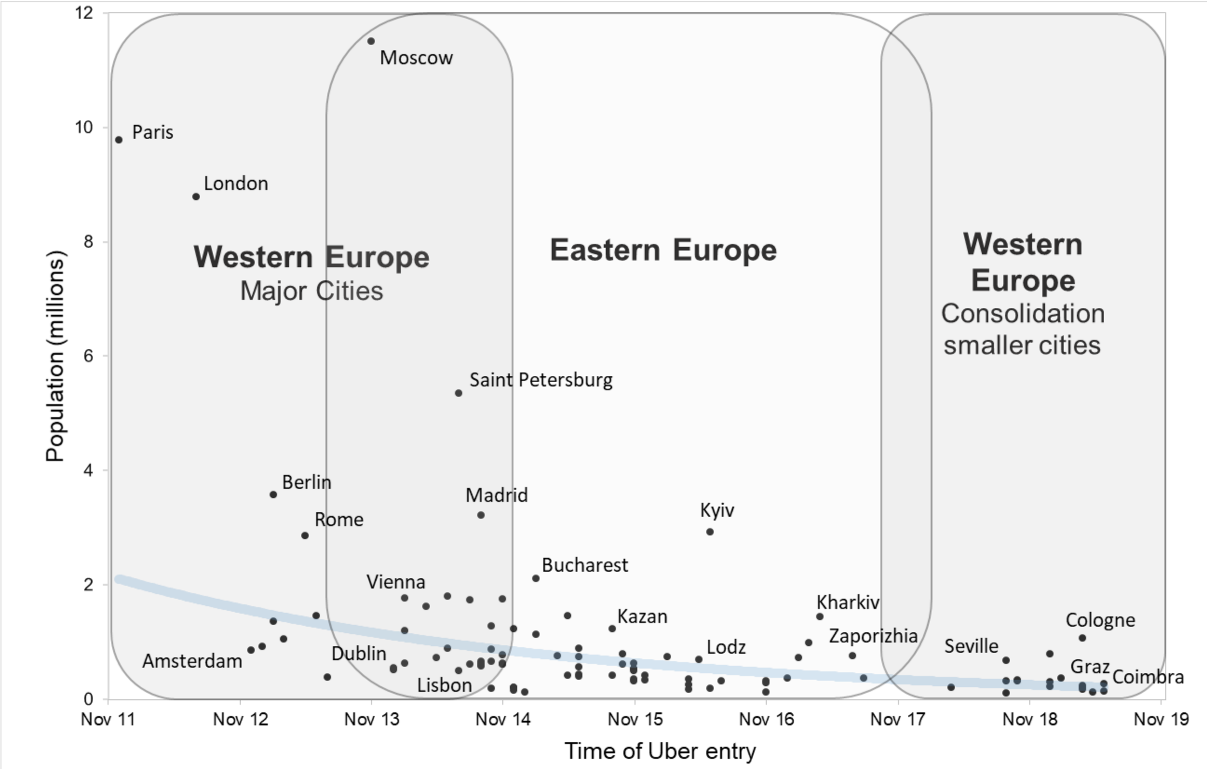

Figure 2.4. Scatter plot of Uber expansion in Europe (city population against time of Uber entry)

2.4.1.2. Imitators and sequential innovators

Unsurprisingly, *Uber*'s success has called competitors to the scene who tried to copy the *Uber* BM (Table *2.4*). They include *Lyft*, *Uber*'s biggest rival in the US market. *Lyft* launched in June 2012 and quickly boasted tremendous success. However, *Lyft* focuses only on North America as their expansion activities so far only included cities in the USA and Canada.

International competition, nevertheless, is equally prevalent as imitators have emerged in many parts of the world. There are a few examples of regions where imitators have been able to establish ride-hailing services before *Uber* was able to roll-out. This refers, for example, to Spain – the home market of *Cabify*. Founded in 2011, *Cabify* launched in Madrid and Barcelona in early 2012. It started by offering "Executive" ride-hailing services with limousines (comparable to *UberBlack*) and later introduced a cheaper "Lite" service (comparable to *UberX* or *UberPop*). In Europe, *Cabify*'s expansion so far only included its neighbor country Portugal. Due to cultural and linguistic proximity (Ghemawat, 2001), it quickly expanded into Latin America, however. As of June 2019, *Cabify* was operating in 10 countries in Latin America, which has become the company's most important market. As especially the "Lite" service enjoys great demand, *Cabify* continues to pursue a geographical concentration strategy in Latin America by adding additional cities to its portfolio. Recognizing regional peculiarities, they have also introduced adjusted services in some cities such as the carriage via motorbikes.

The Estonian start-up *Bolt* is another competitor from Europe. Starting with taxi-hailing services (initially under the name *Taxify*), the company has become a leader in the Baltics region. However, *Bolt* was also aiming for growth and has expanded both its service area and its offering. As of June 2019, it was operating in 34 countries on four continents with a focus on ride-hailing. *Bolt* has become very successful in Africa, where it claims to be the number one ride-hailing company and the first to offer ride-hailing with motorbikes which enjoys great popularity.

Ride-hailing has not only been brought to the developing world through international expansion, instead, several new start-ups have been founded in developing countries as well. The most prominent examples include *Didi Chuxing* and *Grab*. Both emerged as the market leaders in their home market in China and Southeast Asia, respectively.

Other notable ride-hailing companies from developing countries have furthermore modified the ride-hailing BM with regards to vehicle deployment. For instance, *Angkas* from the Philippines and Indonesian *GoJek*, both deploying motorbike taxis, and Indian *Ola Cabs* which also offers services with auto rickshaws.

Table 2.4. Major ride-hailing imitators and sequential innovators

Start-Up	Origin	Launch	Focus Region	Services
Cabify	Spain	2012	Latin America	Ride-hailing
Lyft	USA	2012	North America	Ride-hailing, Bike- and e-scooter sharing
Didi	China	2012	China, Mexico, Australia	Ride-hailing, Taxi-hailing, Carpooling, Bike-sharing
Grab	Malaysia/ Singapore	2012	Southeast Asia	Ride-hailing, Taxi-hailing, Grocery delivery, Parcel delivery, and more
Bolt	Estonia	2013	(Eastern) Europe, Africa	Ride-hailing, e-scooter sharing

2.4.2. Carpooling (commercialization stage)

Carpooling is a form of ridesharing where a driver and up to six passengers share a ride in a private car (Shaheen and Cohen, 2019). Offering carpools usually proceeds without any profit-oriented intention. Instead, the motivation for drivers is to find passengers who are incidentally traveling a similar origin-destination to share the operating expenses. This idea has been in use for decades, especially among family members, neighbors, co-workers, fellow students, and so forth. Internet-based technologies have recently facilitated the pairing of drivers and potential passengers and introduced public carpooling through websites and mobile apps. In this process, carpooling has also expanded from the urban context (such as work trips) to inter-city travel.

On the one hand, carpooling is seen as a very sustainable model among the shared-mobility solutions in terms of reducing congestion, travel resources, and greenhouse gas (GHG) emissions, while on the other hand, it is also believed to be a relatively unattractive alternative for travelers, considering disbenefits in terms of travel time and flexibility (Santos, 2018).

2.4.2.1. BlaBlaCar (market leader)

BlaBlaCar, founded 2006 in France, is one of the pioneers and largest carpooling companies. While the service was initially only available on its online website, most drivers and passengers are now matched through the *BlaBlaCar* mobile app which launched in December 2009. Since the service is meant for inter-city travel, users generate fewer trips compared to shared-mobility services in the urban environment. Accordingly, *BlaBlaCar* operates on a (multi-)national level. The company's internationalization started with launches in Spain (2009) and in the UK (2011), adding several more European countries in the following years. Figure *2.5* shows that the expansion was progressively carried out during separate phases. After expanding to a neighbor country (e.g., Spain), they successively entered countries in the next proximity (e.g., Portugal) – indicating that *BlaBlaCar* pursues a contiguous expansion strategy. In this way, BlaBlaCar creates cross-country network effects through international trips (e.g., from Spain to Portugal and vice versa). While the initial focus was on Western European countries, the expansion then increasingly turned to the East.

It is also noteworthy that *BlaBlaCar*, in addition to its own expansion (e.g., to the UK), has entered several countries through the acquisition of competitors. This refers to the cases in Italy (*PostoinAuto.it*), Ukraine and Russia (*Podorozhniki*), and Hungaria, Croatia, Romania, and Serbia (*AutoHop*). *BlaBlaCar* has also expanded to first non-European countries, namely India, Mexico, and Brazil (all in 2015). These countries, like other emerging economies, certainly provide huge potential due to their large population and megacities (such as Mumbai, New Delhi, São Paulo, and Greater Mexico City), whereas also distinctive downsides such as long distances between major cities and low(er) car ownership are present. Nonetheless, *BlaBlaCar* has not further expanded in the developing world and only launched in the Czech Republic and Slovakia (2016) since then.

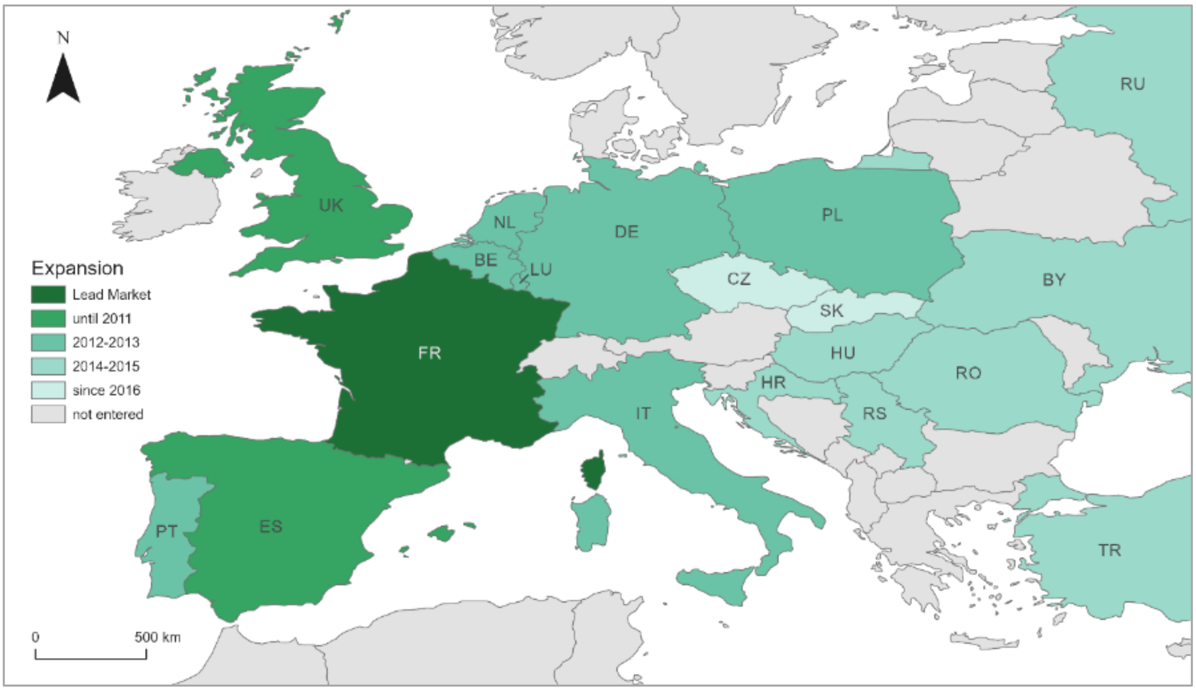

Figure 2.5. BlaBlaCar expansion in Europe

2.4.2.2. Imitators and sequential innovators

In the digital age, drivers and passengers have several options to organize carpools. Amongst others, advertisement websites (e.g., *Craigslist*) and social media (e.g., *Facebook* groups) are being used to match people who want to share a ride. There are also countless smaller and usually less well-known website-based carpooling platforms. But also, more sizable and VC-backed start-ups such as *Zimride*, *Waze Carpool*, and *Wunder Mobility* have emerged in recent years (Table *2.5*).

Zimride, which has later spawned *Lyft*, was founded in 2007. It operates with a concept that is slightly different compared to what *BlaBlaCar* has established in Europe. Universities and companies use *Zimride* to create and promote their own private carpooling network. Addressing the issue of safety, which is a major concern regarding public carpooling (Kelly, 2007), *Zimride* therefore only connects people that are working/studying at the same company or institution. *Zimride*, same as *Lyft*, is currently only available in the USA and Canada.

A more recent player in the carpooling business is the *Alphabet*-owned community-driven GPS navigation provider *Waze*. Leveraging user-submitted travel times and route details, *Waze* is intending to make carpooling operations more efficient and available on intra-city level. *Waze Carpool* has first launched in 2016 in the San Francisco Bay Area and has since expanded to all States in the USA. Regarding the expansion of their carpooling service, which is now also available in Israel, Brazil, and Mexico, *Waze* benefits from already having millions of active users (for the navigation service) worldwide.

Another start-up focusing on intra-city carpooling is *Wunder Mobility* from Germany that was founded in 2014. Besides carpooling, *Wunder Mobility* also provides micro transit services (*Wunder Shuttle*) as well as car and electric scooter-sharing (*Wunder Fleet*). The company is active in more than 50 cities worldwide. However, due to the strict local transport regulation in the German home market (and in many other European countries), *Wunder Carpool* is focusing on emerging markets and is now only available in Brazil and India. Until June 2019, they also operated in MM, Philippines, but have ceased services presumably due to unresolved regulatory issues.

Sequential innovators from developing countries such as Indian *sRide* and *Quick Ride*, furthermore, addressed the issue of low car-ownership and thus introduced motorbike pooling.

Table 2.5. List of major carpooling companies

Start-Up	Origin	Launch	Carpooling Adaptation	Available in
BlaBlaCar	France	2006	Inter-city carpooling	Brazil, India, and 19 countries in Europe
Zimride	USA	2007	Corporate carpooling	USA, Canada
Wunder Carpool	Germany	2014	Intra-city carpooling	Brazil, India
Waze Carpool	USA	2016	Intra-city carpooling	USA, Israel, Brazil, Mexico

2.4.3. Mobility as a Service (early internationalization stage)

Mobility as a Service (MaaS) is a relatively new phenomenon that is currently receiving much attention from both the public and private sector and the scientific community. Due to its novelty, the term is currently being addressed rather vaguely, and there is still no accepted definition for MaaS (Utriainen and Pöllänen, 2018). Nevertheless, in its most prevalent perception, MaaS describes a NMS that combines private and public transport services into a single platform accessible on demand. Several start-ups and initiatives are being associated with this concept, although they greatly differ in terms of service features and functionality. In this context, Kamargianni et al. (2016) identified four main elements of MaaS schemes. They are ticket, payment, and ICT integration as well as the offer of mobility packages (also mobility plans or bundles). We support the view that these elements, in conjunction, have the greatest impact to provide a seamless intermodal user-experience that could significantly shape the future of urban transport. In the following, we therefore consider those services that contain all four elements as “full” MaaS schemes.

2.4.3.1. MaaS Global (market leader)

The provider of the first full MaaS scheme is Finnish start-up *MaaS Global*. Their service – called *Whim* – was launched in November 2017 in Helsinki, Finland. Currently, it offers a “pay-as-you-go” service as well as three different mobility packages with limited or unlimited mobility services. In the media and in the popular press, *Whim*’s Helsinki model is considered a success and a guide for future urban transport. Within the first two years of operation, the company claims that 20,000 registered *Whim* users have completed about two million trips.

International expansion started in Birmingham/West Midlands, UK and Antwerp/Flanders, Belgium, where full services started in March 2018 and October 2018, respectively. In October 2019, *Whim* also launched in Vienna, Austria. According to *Whim* Co-Founder Kaj Pyyhtiä, however, this marks only the beginning of its internationalization as their goal is to cover 60 countries until 2023 (ITS International, 2018). For any future expansion, partnerships with authorities (to provide favorable conditions to operate a MaaS system) and local companies (to provide the transport services) will be necessary. Among many factors, the strong commitment and support by the public sector, including the Finnish Ministry of Transport, was crucial for Helsinki to become the pioneer city for MaaS (Audouin and Finger, 2018). In general, transport providers are expected to be interested in bundling services (Mulley et al., 2018) and joining a MaaS scheme to increase market shares and revenues (Polydoropoulou et al., 2018). However, they would need to agree that the MaaS operator collects a commission and would be required to open data to third parties. Due to the involvement of many stakeholders (with different and competing interests), building partnerships, thus, appears to be *MaaS Global*’s biggest challenge to become "global".

2.4.3.2. Imitators and sequential innovators

Between November 2013 and April 2014, a full MaaS scheme was tested during a 6-month field trial in Gothenburg, Sweden. Despite the positive feedback that 97 % of participants (N=195) would like to continue using the service called *UbiGo* (Karlsson et al., 2016), full operation has not yet started – however, a second pilot is currently being tested in Stockholm.

Another full MaaS scheme called *SHIFT* was available in Las Vegas, USA. Instead of integrating different transport providers and services on a single platform (Helsinki model), the start-up operated completely with its own vehicles. In 2015, however, the service was shut down after two years of operation. Therefore, to the authors' knowledge, *Whim* is currently the only available full MaaS scheme worldwide. Their potential competitors for the future, nonetheless, are numerous. Transport providers from the rail (Deutsche Bahn/ioki), public transport (BVG/Jelbi; Hamburger Hochbahn/switchh), and the car rental industry (Europcar Groupe/Ubeeqo) have already introduced own platforms. Also, transport authorities (Transit Authority of River City/TARC; Roads and Transport Authority Dubai/S'hail) and cities (City of Graz/tim) are working on MaaS solutions. Even carmakers are changing their business strategies and are entering the mobility ecosystem (Daimler/moovel; Groupe PSA/Free2Move). Finally, large tech and conglomerate companies are gaining a foothold in the market and deliver own solutions or the necessary technology (IBM France/Optimod'Lyon; Siemens/SiMobility). The mentioned projects, however, currently only provide a partial integration or are still in a pilot or research phase (Table *2.6*).

Table 2.6. List of MaaS schemes

MaaS Scheme	Launch	Integration type	Available in
TransitApp	2012	Partial	125+ cities in USA, UK, Canada, Europe, Australia
moovel	2012	Partial	Stuttgart, Hamburg, Vienna, Portland
SHIFT	*2013*	*Full*	*Las Vegas*
UbiGO	*2013*	*Full*	*Gothenburg, Stockholm*
switchh	2013	Partial	Hamburg
Optimod'Lyon	2015	Partial	Lyon
Ubeeqo	2015	Partial	Barcelona, Madrid, Berlin, Hamburg, Brussels, London, Milan, Paris
tim	2016	Partial	Graz
Free2Move	2016	Partial	20+ cities in Germany, France, Spain, Italy, UK, Austria, USA, Belgium
Whim	2016	Full	Helsinki, Birmingham, Antwerp, Vienna
S'hail	2019	Partial	Dubai
TARC	2019	Partial	Louisville (Kentucky)
Jelbi	2019	Partial	Berlin

Italic marks MaaS schemes that are not operational anymore (SHIFT) or that are still in a pilot/research phase (UbiGO)

This list makes no claim to completeness

2.5. Discussion of results

2.5.1. Business model and network effects

Our analysis shows that *Uber* has experienced the most rapid evolution (Figure *2.6*), which among other factors can be attributed to its highly replicable BM. *Uber* has launched their service in dense urban areas worldwide, where they serve similar user needs and provide an efficient alternative to incumbent services (e.g., taxi or public transport). Across different markets and countries, the ride-hailing BM only requires minor adjustments such as the use of different vehicles. *BlaBlaCar*'s BM, on the other hand, is conceptualized for the long-distance market at inter-city level. They therefore seek countries and regions with a constellation/dense network of large cities located within a few hundred kilometers from each other. These conditions are generally found in Europe, where the platform has grown steadily. While inter-city carpooling therefore appears to be only viable in Europe, *Zimride*'s corporate carpooling has not outgrown the North American market. Thus, the carpooling BM provides only low replicability potential (hence, the "need" for different firms to make adaptations to the BM). The MaaS BM even needs to be adjusted in every context, depending on the existing regulation, available transport services, and so forth. For this reason, the replicability of the MaaS BM appears to be low, which could explain the very low number of operating MaaS schemes so far.

The analysis further underlines that the *Uber* BM is highly scalable. It provides strong incentives on both user sides, whereby the trigger to initiate transactions is located on the demand side. Through the *Uber*-app, passengers can conveniently book trips online. Most users make use of the service regularly and book rather short trips (Rayle et al., 2016). This makes it attractive for professional drivers to join the platform as well. Online accessibility and the efficient matching allow a high utilization of resources, making it easier to reach a critical mass. In contrast, carpooling follows a "supply push" approach, where non-professional drivers offer seats on private trips. Even if these drivers would regularly provide carpools (e.g., on their daily commute), the total number of offered trips would usually still be quite low. As carpooling does not intend any profit-making, there are not many incentives for drivers to offer additional trips. Also, most users would not frequently demand long-distance trips. Compared to NMS in the urban environment (e.g., ride-hailing), fewer transactions are therefore generated. The scaling potential of the carpooling BM is therefore rather low. For MaaS schemes, scaling is linked to several challenges and uncertainties (e.g., related to governance and stakeholder commitment). Once a MaaS scheme is able to unify several existing service providers and transport modes under its platform, it instantly covers a significant number of urban trips. While the BM design in theory seems very promising, its implementation is fairly difficult. We thus classify the potential for scalability of the MaaS BM as rather low/medium.

While *Uber* and *MaaS Global* are generating significant network effects in the urban environment, only *BlaBlaCar* considerably generates cross-country network effects as they enable cross-border carpooling trips. However, this only applies to countries in close geographical proximity. Therefore, the geographic scope of network effects does seemingly not (or only to a certain degree) play a determining role in the internationalization activities of mobility platforms.

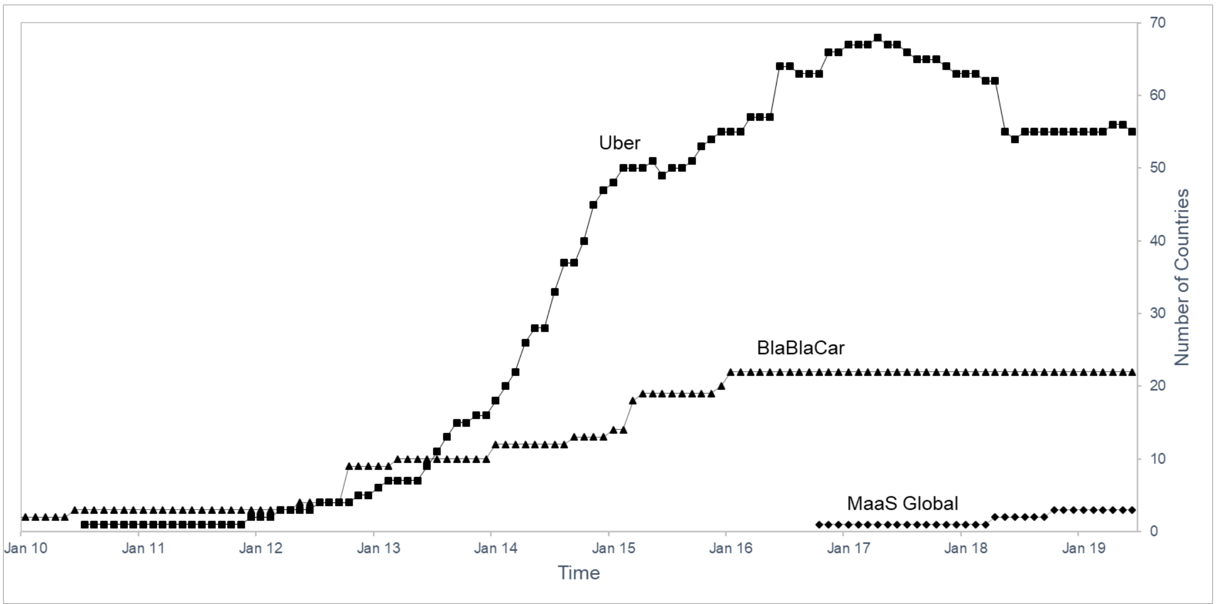

Figure 2.6. Expansion of market leaders over time (Jan 2010 – Jun 2019)

2.5.2. Competition and expansion strategy

Among the analyzed NMS, ride-hailing represents the most competitive market. The market leader, *Uber*, is facing strong competition at both the home market (i.e., *Lyft*) and internationally (i.e., *Cabify*, *Bolt*, *DiDi Chuxing*, *Grab*, etc.). In many profitable markets, *Uber* is fighting over market shares with at least one competitor (in addition to the intermodal competition). To maintain the required growth, *Uber* thus followed an aggressive expansion strategy and targeted dense urban areas all around the globe (geographical diversification strategy). Hall et al. (2018) have cited *Uber* officials claiming that their goal was to cover as much of the US and the world as soon as possible. Enabled through the replicable BM, *Uber* has thus entered new markets shortly after another or even simultaneously (sprinkler strategy).

While *BlaBlaCar*'s strongest competition is coming from alternative transport modes such as long-distance buses and trains, rather small regional competitors have frequently been acquired as part of their expansion strategy. *BlaBlaCar* first targeted country markets in the next proximity that they entered during different phases (waterfall strategy). Furthermore, *BlaBlaCar* has primarily focused on the European market (geographical concentration strategy), in countries where its BM is replicable and where carpooling was already established.

Even though there is a huge interest in the MaaS market and several prospective Maas players, *MaaS Global* has not faced any direct competition on local level so far (i.e., another MaaS provider competing in the same city). Such a situation seems also unlikely to occur in the future as MaaS rather leads to an "all-or-nothing" scenario (Hasselwander, 2019). In addition, in case *MaaS Global* maintains its position as the market leader for MaaS, one could expect that it acquires regional MaaS start-ups or cooperates with local entities to set a foot into new markets in the future. Presumably, mostly in cities with similar conditions as in their home market (e.g., in Europe).

2.5.3. Diffusion patterns of NMS

Building on the observations from the three case studies, we draw two diverging diffusion patterns for NMS that differ in terms of speed, intensity, and driving forces involved (Figure *2.7*).

We found that mobility platforms with scalable, replicable BMs that are facing fierce competition (i.e., high number of sizable competitors on local and international level) – such as in the ride-hailing case – aim to expand quickly which enables a rapid diffusion of the concept and a short time to reach the globalization stage. In such cases, the market leader is typically the driving force and introduces and establishes the NMS in several new markets (e.g., as observed by *Uber*). At the same time, international competitors contribute to the uptake of the NMS, but typically not as a first mover or only in selected niche markets (e.g., *Cabify* in Latin America).

In contrast, the carpooling concept represents an example for a gradual diffusion. The carpooling BM provides less potential in terms of scalability and replicability. Hence, the market leader and different sequential innovators push forward the NMS with adjusted BMs in geographically concentrated markets (e.g., *BlaBlaCar* in Europe and *Zimride* in North America). A direct competition among major carpooling companies within the same market is often non-existent. This leads to a slower global diffusion of the concept and a longer period required to reach the globalization stage.

Regarding MaaS, the initial expansion activities of the innovator point to a gradual diffusion. *MaaS Global*'s BM is not easily replicable/implemented and is difficult to scale. While the concept is therefore still in its early internationalization, we note that the uptake of MaaS also depends on public policies, stakeholder commitment, and regulatory change (Karlsson et al., 2019). This brings new players (e.g., cities and transport authorities) on the agenda that could accelerate MaaS diffusion. While there seems to be some evidence that the public sector is indeed pushing for MaaS and integrated transport (Smith and Hensher, 2020), this was not part of our analysis. We therefore recommend addressing this aspect in future research.

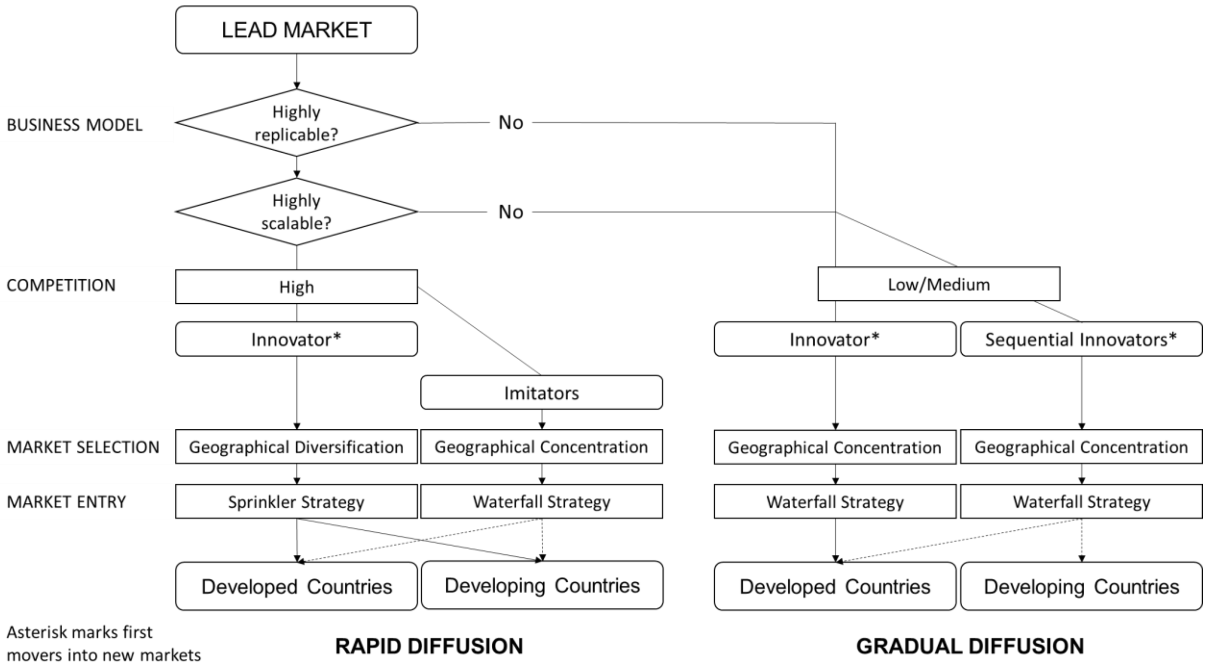

Figure 2.7. Diverging diffusion patterns in the mobility ecosystem

2.6. Conclusion

This research has performed an analysis on the internationalization of mobility platforms based on multiple cases (ride-hailing, carpooling, and MaaS). The results confirm the a priori advanced Proposition 1 that the rapid or gradual internationalization of mobility platforms implicate a rapid or gradual diffusion of the respective NMS. Thereby, the type of internationalization indeed depends on several factors (Proposition 2). Most of all, this relates to the BM. It is the main determining factor that also influences the underlying competition (e.g., successful BMs create increased competition through imitators), the type of expansion strategy, whether markets can be entered as first movers, and, subsequently, whether the NMS diffuses rapidly or gradually. While network effects are essential for the growth of mobility platforms, we found that cross-country network effects do not essentially lead to a faster internationalization. The results further underline that mobility platforms determine when and where users initially can adopt a new service by making it available – usually via a mobile app – at the first place. This observation is crucial when trying to anticipate the worldwide diffusion of NMS.

Based on these results, we emphasize that the mobility ecosystem is proving to be very dynamic and mainly driven by the private sector. We further support findings by Ojala et al. (2018) and show that many platforms in this ecosystem are early adopters of internationalization.

This knowledge is of particular interest in terms of managerial practice, that is, industry decision-makers gain a more comprehensive understanding of mobility platforms' market selection, expansion, and competition strategy. Considering the developments towards multimodal transport including the integration of public and private transport modes, this does not only concern decision-makers from mobility start-ups, but from the entire passenger transport industry including public transport operators, car rental companies, and other incumbent market participants.

The present study highlights the role of developing countries and the interrelations in a global mobility ecosystem that have been rarely discussed in the literature, and thus inaugurates several new research opportunities. Being in its early internationalization, especially MaaS is a near to unsearched field in the context of developing countries. Since our analyses only covered NMS that rely on the platform BM, the global diffusion of other mobility solutions, such as bike- and electric scooter-sharing – in which the assets are typically owned by the service providers – also merit additional research.

Chapter 3

3. Building back better: The COVID-19 pandemic and transport policy implications for a developing megacity

3.1. Introduction

The outbreak of the COVID-19 disease caused by a novel coronavirus (SARS-CoV-2) has changed and will continue to change our world radically. First registered in December 2019 in Wuhan, China, the coronavirus has quickly spread across countries and territories. On March 11, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic (WHO, 2020a). By the end of September 2020, at least 34.2 million cases were registered worldwide, while the total number of related deaths had exceeded one million (WHO, 2020b). Undoubtedly, the current pandemic has a significant impact on everyday life. This relates to social norms, consumer behavior, habits and customs, or simply put, the COVID-19 outbreak has changed the way we live, behave and interact (Prosser et al., 2020; Sheth, 2020). Like any pandemic before, however, the COVID-19 pandemic will end. Nevertheless, the long-term economic consequences are expected to be perceptible for several years in the form of a global recession (Lenzen et al., 2020), and we will likely have to adapt to a “new normal“ in different contexts and many parts of life.

Certainly, a “new normal” is to be expected for the transport sector.

On the one hand, it is widely known that transport is a potent force in disease emergence and spread as human-incubated pathogens or disease vectors can be moved large distances in short time (Tatem et al., 2006). Several studies highlight the role of air transport in the propagation of infectious diseases even to distant locations (e.g., Findlater and Bogoch, 2018). Studies have further identified an increased risk of disease infections (e.g., tuberculosis) in public transport vehicles (e.g., Andrews et al., 2016; Feske et al., 2016). Due to this relationship, researchers frequently try to model the spreading of infectious diseases through transport data, as also in the current case of COVID-19 (e.g., Du et al., 2020; Iacus et al., 2020; Kraemer et al., 2020; Wu et al., 2020). These studies suggest that transport indeed contributes to the geographical spread of the coronavirus. However, recent studies, including a comprehensive study in Germany, found no evidence of an increased risk of SARS-CoV-2 infection while traveling on public transport[2].

On the other hand, pandemics also have an impact on transport and human mobility, considering the immediate effects of lockdowns, social distancing rules, home quarantines, and the full or partial suspension of transport services. Unsurprisingly, public transport – where it remained in operation – experienced a significant drop in ridership (Shakibaei et al., 2021; Tirachini and Cats, 2020). Individual motorized traffic has increased in many cases to avoid social contacts while traveling. Nevertheless, it is only available to those with access to private vehicles and linked to other negative externalities such as noise and air pollution. Active mobility is also experiencing a renaissance, especially as an alternative to mass transit (Nurse and Dunning, 2020). However, many cities – mainly in the global South – do not provide adequate infrastructure to enable safe and efficient walking and cycling (e.g., Bakker et al., 2018).

Even in the midst of a health crisis – or precisely because of it – essential and frontier workers, as well as many others, depend on access to mobility. Due to the mentioned constraints, the transport sector is therefore in an unprecedented situation, causing a paradigm shift in which it needs to change its role and function in society (Kim, 2020). Most likely, many of these changes are not just temporary. Indeed, scholars expect that the current pandemic will also have a long-term impact on transport infrastructure and operations, travel behavior, mode choice, and so forth (e.g., De Vos, 2020; Tirachini and Cats, 2020).

The authors of this study are particularly interested in how these changes may transform transport systems in urban areas, where people (55 % of world’s population) and economic activities (more than 80 % of global GDP) are concentrated (World Bank, 2020b), and that are highly vulnerable to pandemics (UN, 2020). More specifically, we are interested in megacities[3] in the global South that in the current COVID-19 crisis, in particular, were confronted with acute stresses due to larger populations and densities that accelerate disease transmissions, especially in low-income communities (Dahab et al., 2020; Das et al., 2021; Ren et al., 2020).

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[2] During the first phase of the on-going Robert Koch Institute study, a representative sample (N=1073) of Deutsche Bahn train personnel was tested for active (PCR test) and past infection (antibody test) with SARS-CoV-2. It found that train attendants with frequent passenger contact did not have a higher infection rate than the comparison groups (train drivers and craftsmen) without customer contact. Further information on this study can be found at https://www.drks.de/drks_web/navigate.do?navigationId=trial.HTML&TRIAL_ID=DRKS00022359

[3] We follow the definition by the UN DESA (2019), according to which megacities are the largest category of urban agglomerations with 10 million inhabitants or more.

The objective of the study is to outline transport policy implications for developing megacities, as a resilience and mitigation strategy to forthcoming pandemic outbreaks and other disruptions, and to shape more sustainable transport systems. We argue that every crisis offers an unprecedented opportunity for structural change for the better. Given the crucial role of transport in modern societies, for economic growth, and for people's health and well-being, the urgency of effective transport policies is highlighted. Our case study focuses on MM, a developing megacity in Southeast Asia that experienced one of the longest and most stringent lockdowns worldwide (Hale et al., 2020). The study uses aggregated open-source location and trip data from two sources. Similar to existing studies (e.g., Arellana et al., 2020; Tamagusko and Ferreira, 2020; Yilmazkuday, 2021), statistical analyzes are used to compare and quantify how the population's mobility behavior has changed since and during the crisis. Based on insights from the analysis and from the available literature, we then develop evidence-based policy recommendations for developing megacities.

Our study responds to calls for more research on COVID-19 impacts in developing countries (Mogaji, 2020) and their megacities (Shakibaei et al., 2021). While many studies outline generalized findings (e.g., De Vos, 2020; Tirachini and Cats, 2020), developing megacities indeed merit a separate investigation due to their distinctive features (Canitez, 2019). Addressing this research gap, our study uses big data covering more than six months, which therefore represents one of the first longitudinal case studies on COVID-19 impacts. We also present the first transport study related to COVID-19 in Philippine context (Kutela et al., 2021). In addition, the study contributes to the very timely research fields of transport and health (Musselwhite et al., 2020) and post-pandemic urbanism (Megahed and Ghoneim, 2020).

The remainder of this chapter is structured as follows. The following section presents further information on our case study. Section 3 details our data sources and methods. Results are presented in Section 4. We then discuss policy implications (Section 5) as well as research limitations and future research lines (Section 6). Finally, concluding remarks are presented in Section 7.

3.2. Case study presentation: Metro Manila, Philippines

The Philippines is an archipelagic country located in Southeast Asia that consists of more than 7,600 islands. It is classified as a lower-middle-income country (World Bank, 2020a) and has a population of almost 110 million. Its national capital region of MM – located on the island of Luzon in the Northern part of the country (Figure *3.1*) – represents the country's center of culture, economy, education, and the seat of government. MM comprises 16 cities and one municipality and occupies an area of about 620 km². With about 13 million inhabitants (density of 20 thousand persons per km²), it is one of the most populous urban areas in the world.

MM presents many distinctive transport characteristics that developing megacities have in common (e.g., premature traffic congestion, high motorization rates, and deteriorating environmental conditions) (Gwilliam, 2003) and which are often in contrast to large metropolises in the global North. Due to the lack of mass transit solutions (the rail transit network with three different lines only covers 75.2 km), the public transport systems in MM are predominated by road-based services that include buses, jeepneys (local 12 to 16-seater paratransit vehicles), UV Express (a point-to-point microbus service), and tricycles (a local auto rickshaw version). According to past transport planning studies (JICA, 2015), public modes constitute for about 49 % of trips in MM, private modes for about 20 % (11.5 % of households are car owner), and walking for about 30 %.

For more information, the reader is referred to most recent MM case studies in the transport literature that describe vehicle ownership (Rith et al., 2019), service quality of paratransit services (Tiglao et al., 2020), and on-going public transport reforms (Mateo-Babiano et al., 2020; Sunio et al., 2019; Sunio et al., 2020), among others.

3.2.1. The COVID-19 outbreak: key events and government responses

Due to the geographical proximity and the close bilateral connection to China, where the outbreak originated, the Philippines was one of the first countries to report SARS-CoV-2 infections. The Department of Health - Republic of the Philippines (DOHRP) confirmed the first positive case on January 30. It concerned a Chinese citizen from the Hubei province who entered the Philippines on January 21 from Hong Kong. The second confirmed case was the first case's companion. That person's death on February 1 was the first recorded outside China (Bautista and Luz Lopez, 2020). The first local transmission of SARS-CoV-2 in the Philippines, concerning a person from one of MM's adjoining provinces without travel record abroad, was confirmed on March 7. In the following, the total number of cases in the country increased sharply. MM hereby developed into the main COVID-19 hotspot in the Philippines (Figure *3.1*).

In response to the evolution of the disease, several governmental measures were imposed at national and regional levels. The first measures encompassed international travel restrictions. On January 23, all flights from Wuhan (to Kalibo, Aklan) and on January 31, all other flights from the Hubei Province to the Philippines were suspended. By February 10, all travelers from entire mainland China, Hong Kong, Macau, and Taiwan were banned. Tourist travels to South Korea, where high numbers of cases were being recorded, were prohibited on February 26. In the following, also other countries with local transmissions were banned until all visa issuances were finally suspended on March 19.

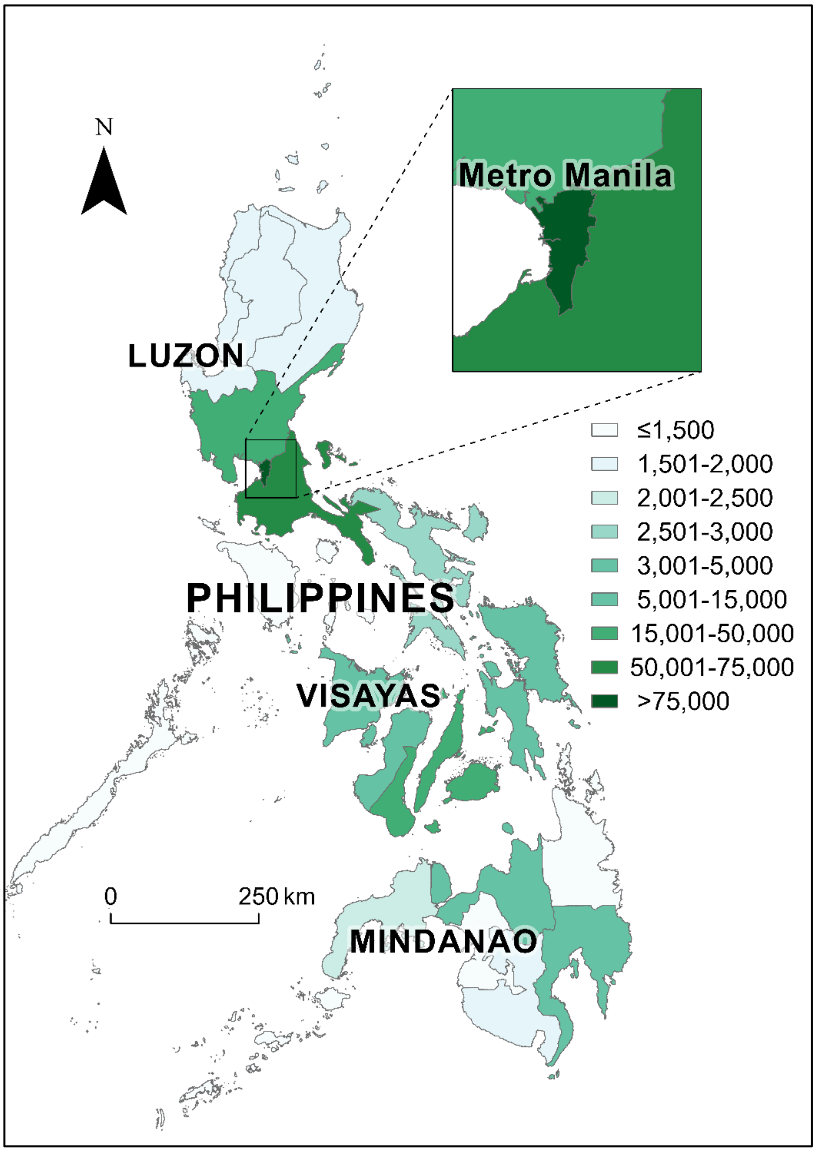


Figure 3.1. Total number of COVID-19 cases per region in the Philippines (as of September 30, 2020)

Data from DOHRP, 2020; PhilGIS.org

After the first local SARS-CoV-2 transmissions were recorded in MM, the government declared a public health emergency on March 8. MM was initially placed under a strict lockdown and state of calamity on March 15, which prohibited land travel, local air travel, and local sea travel from and to the city. Two days later, on March 17, an *enhanced community quarantine* (ECQ) was extended to the entire Luzon island. In response to changing health situations in the following weeks and months, the quarantine status has been adjusted several times, i.e., into *modified enhanced community quarantine* (MECQ) and *general community quarantine* (GCQ). Table *3.1* summarizes the different phases of the lockdown and its associated measures. For additional insights regarding the (early) lockdown protocols in MM, the reader is referred to Ocampo and Yamagishi (2020).

Table 3.1. Timeline of government response in Metro Manila: containment and closure policies

Quarantine state	Description
ECQ (17.03.-15.05)	- strict instructions for staying at home (except for health and essential workers), restriction of people's movement, no gatherings allowed - complete suspension of public transport services (minimal level of operations only maintained for health and essential workers) - closure/reduced capacities of non-essential businesses - establishment of alternative working arrangements (e.g., teleworking) - suspension of classes at all schools, colleges, and universities - ban of public events and gatherings (except for essential government services and humanitarian activities)
MECQ (16.05.-31.05.)	- gatherings of max. 5 persons - limited reopening of selected businesses - small gatherings and selected leisure activities allowed under strict conditions (e.g., wearing face masks, practicing good hygiene)
GCQ (01.06.-03.08.)	- approval of selected mass gatherings (e.g., work assemblies) - opening of more non-essential sectors and businesses - provision of limited transport services (4,600 out of the 12,000 bus units) with reduced capacities (e.g., no seating next to each other) - permission of selected holiday and additional leisure activities - face-to-face classes remained suspended
MECQ (04.08.-18.08.)	- return to stricter measures to prevent collapse of the health system amid highest surge in COVID-19 cases since start of the pandemic
GCQ (since 19.08)	- return to more relaxed measures; effective through the information cut-off for this article at the end of September

Data from Bautista and Luz Lopez (2020), Hale et al. (2020), and WHO (2020c).

3.2.2. Development of number of cases and global comparison

As of September 30, 311,694 COVID-19 cases and 5,471 related deaths nationwide were officially confirmed, of which 163,780 and 2,656 respectively are related to MM (DOHRP, 2020). Thus, the capital region accounts for about half of all cases and related deaths nationwide, with the population making up only about 11 % of the country.

Together with Indonesia, the Philippines emerged as the most affected country in Southeast Asia (Table *3.2*). In a global comparison, only 20 countries have reported more cases (WHO, 2020b). However, due to underreporting, limited testing capabilities, and insufficient healthcare access, a significant number of unrecorded cases is expected (Lau et al., 2020). This assumption is supported when comparing the Philippine's positivity rate (the number of positive tested individuals as a percentage of the total tested individuals) with that of other countries. According to the official data by the DOHRP, the cumulative positivity rate for the Philippines is 10.5 %. South Korea and Australia, both known for its extensive nationwide testing, only have a positivity rate of 1.0 % (MOHW, 2020) and 0.4 % (AGDOH, 2020), respectively.

Table 3.2. COVID-19 cases in some Southeast Asian countries (as of September 30, 2020)

Country	Population ('000)[a]	Total Cases[b] / (per 1M pop.)	Total Deaths[b] / (per 1M pop.)
Indonesia	273,524	287,008 (1,049)	10,740 (39)
Malaysia	32,366	11,224 (347)	136 (4)
Philippines	109,581	311,694 (2,844)	5,471 (50)
Singapore	5,850	57,765 (9,874)	27 (5)
Thailand	69,800	3,564 (51)	59 (1)
Viet Nam	97,339	1,094 (11)	35 (0)

[a] Source: United Nations World Population Prospects 2019

[b] Source: DOHRP, 2020; WHO, 2020b

The evolution of reported cases per day in Manila and the Philippines – a key metric for assessing the extent of the pandemic – is shown in Figure *3.2*. It shows that from the beginning of the pandemic to around August, the number of daily cases has risen steadily for both MM and the Philippines. From the first infection in the country on January 30, it took 131 days until a total of 50,000 cases were reported. It took another 26 days for that number to double to 100,000, and 13 more days until the number of cases reached 150,000. Eventually, the mark of 200,000 cases was surpassed after additional 12 days on August 26.

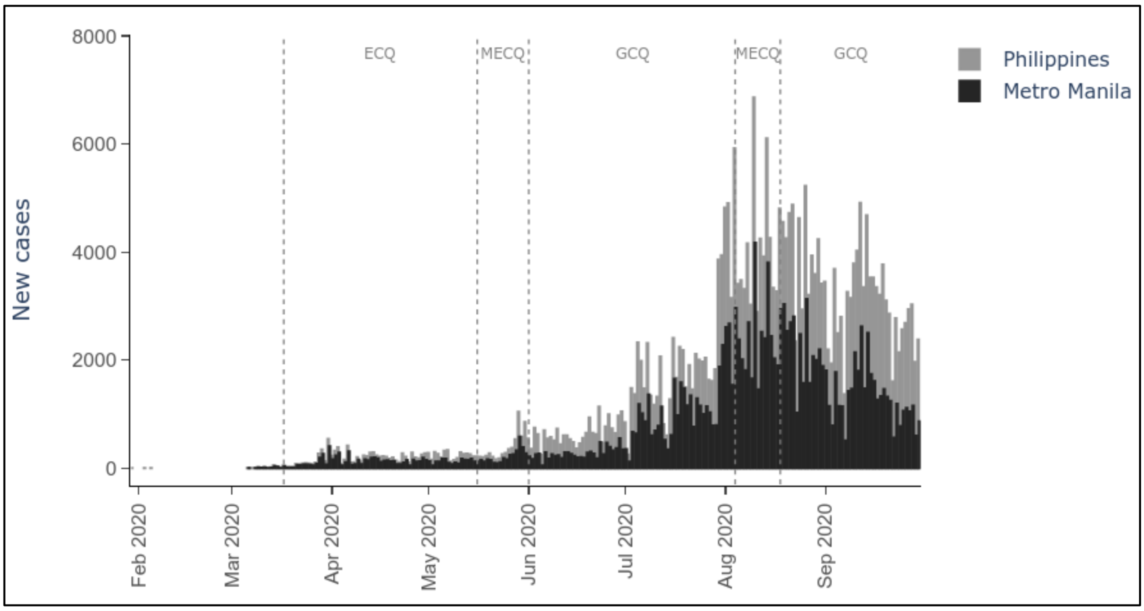


Figure 3.2. Daily new cases of COVID-19 in Metro Manila and the Philippines (as of September 30, 2020)

Data from DOHRP, 2020

This rapid development during the first months could be explained by the exponential growth dynamics of the virus as well as the increase in testing capacity over time (DOHRP, 2020). However, it also suggests that the measures imposed by the government, as described in the previous sub-section, have not been effective in terms of the goal of "flattening the curve" as successfully achieved in other countries such as Thailand and Viet Nam. A very drastic increase in cases was observed in late July and the beginning of August, which appears to correspond to the (first) peak of infections. While most countries worldwide started easing COVID-19 measures during this time, the Philippines was thus forced to temporarily return to a more stringent lockdown. However, that trend has flattened since September and a decline in the number of daily reported cases was recorded.

3.3. Data and methods

In this study, we use aggregated open-source cell phone and GPS data from two sources that provide a comprehensive representation of the mobility behavior of the MM population before and during the lockdown.

Specifically, we used the following data sources. First, the *Google COVID-19 Community Mobility Reports* which provide anonymized and aggregated daily data on population location patterns during the COVID-19 crisis (Google, 2020). The location patterns describe visits to different sites and locations, which are divided into six categories (Table *3.3*). The data values vary between -100 and 100, with 0 being the baseline for the pre-COVID-19 level. The baseline corresponds to a sample period prior to the pandemic (January 3 - February 6, 2020). Positive variations relate to increases to the baseline, whereas negative values indicate a reduction. Data aggregation and the generation of reports are described in Aktay et al. (2020), while more information is also available from the data provider (Google, 2020).

Table 3.3. Google COVID-19 Community Mobility Reports - Report categories

Category	Subcategories
Retail and recreation	Restaurants, cafes, shopping centers, theme parks, museums, libraries, and movie theaters
Grocery and pharmacy	Grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies
Parks	National parks, public beaches, marinas, dog parks, plazas, and public gardens
Transit stations	Public transport hubs such as subway, bus, and train stations
Workplace	Places of work
Residential	Places of residence

Second, the *Apple Mobility Trend Reports* was used. The reports record changes in route requests since January 13, 2020 and thus describe citizens' (intended) trip patterns (Apple, 2020). It uses anonymous data (received in random identifiers) based on the Apple Maps service and is grouped into three mode categories (driving, transit, and walking). The values provided by Apple are based on a macro similar to that used by Google. However, the Apple data uses a baseline of 100, with negative variations below 100, and positive variations above. In order to facilitate the analysis and comparison, we normalized the Apple data to a baseline of 0 (same as Google's). In addition, we need to mention that the data values for May 11 and 12 are not available. However, we expect the missing data only to have a marginal impact on the analysis and results. Finally, in contrast to Google's location data, requests for route instructions in Apple data are computed. In this study, both data sets are therefore treated individually, as there is no equivalence between the user's actual position (Google) and the indication of an intention to travel (Apple).

With regards to the COVID-19 cases, we rely on the official data drop by the DOHRP (DOHRP, 2020). Note that we refer to the variable *DateRepConf* (date of reporting of confirmed cases) which comprises definite and immutable values. In contrast, the values for *DateOnset* (date of onset of illness) – which is also often used in official communication – are not always available for every case and may change retrospectively.

Based on the available data, statistical analyses were used to estimate changes in mobility behavior and outline trends in location and trip patterns. A changepoint for mobility values based on Google data was obtained using the Changepoint framework (Killick and Eckley, 2014). Following the “at most one change” (AMOC) method (Hinkley, 1970), it determines at 95 % confidence level on which day (threshold) the mobility values changed trends. Simply put, this statistic shows when exactly the population adapted their mobility behavior, for example, in response to a specific event or measure.

Data processing and statistical analysis were mostly performed in Python, while for the changepoint analysis R software was used. The processed data and the code for the changepoint analysis are available at https://github.com/tamagusko/manilaCovid19.

In the last step, we place the evidence from MM against a backdrop of findings from similar studies to derive and discuss policy implications for developing megacities.

3.4. Results

Based on the Google data, Figure *3.3* shows the location patterns of the MM population by reporting category for the period between February 15 and September 30. The first notable variation was observed on February 25. This can be explained by a public (non-working) holiday that happened on that day. Thus, this variation is likely not associated with any COVID-19 related event or measure. Thereafter, a noticeable change in mobility behavior can be observed from the time the local SARS-CoV-2 transmissions started (March 7 onwards). The implementation of the ECQ on March 17, eventually, corresponds to a further drastic change in mobility activities. Also, a significant deviation relates to the mobility levels during the different phases of the lockdown. As could be expected, the state that corresponds to the least restrictions (GCQ) exhibits the closest pattern to the pre-COVID-19 baseline.

Figure 3.3. Google location patterns in Metro Manila (as of September 30, 2020)

While five out of the six categories show a drastic decline that is only recovering very slowly, the *residential* category has been consistently above the baseline level since the initial lockdown. This phenomenon can easily be associated with the COVID-19 policies and the requirement/recommendation for citizens to stay at home. The category *grocery and pharmacy* shows local peaks (+10 on March 10, +/-0 on August 3) shortly before the ECQ/MECQ became effective on March 17 and August 4, respectively. This is likely to be explained by so-called "panic buying". All remaining categories fell below baseline on March 10 or earlier and remained significantly below that level through the end of the analysis period (on September 30, -42.4 on average), whereby *transit stations* clearly lags below the average (-63). The most severe decline was observed for the *transit stations* category, reaching a level of -95 on April 10, followed by *parks* (-93, May 1), *retail and recreation* (-92, April 10), *workplaces* (-87, April 10), and *grocery and pharmacy* (-80, April 10). *Residential* constantly remained on a level of +16 and above. The decline in the *workplaces* category is particularly striking, considering that on the non-working holiday in February that value only dropped to -46. It is noticeable that *parks* as well as *retail and recreation* saw a sharp rise after the return to the GCQ on August 19, suggesting that citizens started to engage more in leisure activities.

Figure *3.4* compares the location patterns during the more stringent (M)ECQ and the more relaxed GCQ. It highlights that *transit stations* experienced the largest drop during both phases, on average, -87 during (M)ECQ and -66 during GCQ. This corresponds to an increase of +21 after the relaxation of the lockdown measures. Compared to the other categories, this represents the slightest recovery – which, however, could result due to the bias (section 3.6) that lower-income segments are underrepresented[4]. During GCQ, *workplaces* increased by +24, *retail and recreation* by +28, *grocery and pharmacy* by +29, and *parks* by +30. As can be expected, the value for *residential* decreased during GCQ (-9).

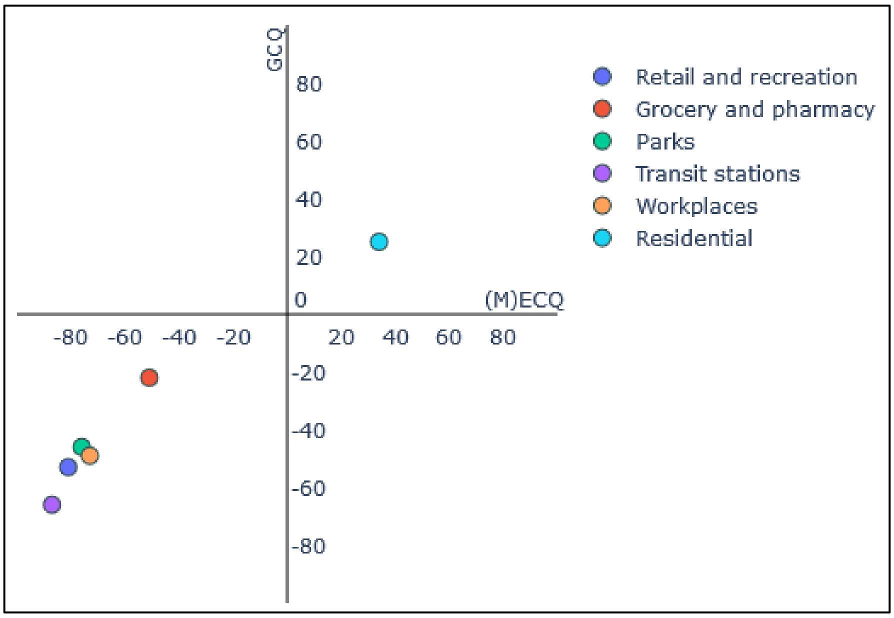


Figure 3.4. (M)ECQ vs. GCQ location patterns in Metro Manila

Time period: 2020/02/15 - 2020/09/30

Regarding the changepoint analysis (Figure *3.5*), it was possible to find the most significant threshold for each location category at which the population statistically changed their mobility behavior. The change in mobility behavior for the respective categories occurred on March 14-16 and thus shortly before the first ECQ came into force (on March 17). Given the immediate impact on the citizens' mobility behavior, this underlines the stringency of the COVID-19 containment policies, including their compliance by the population.

[4] Existing research highlights that lower-income segments are less likely to have the opportunity to work from home (Hatayama et al., 2020), which means that the recovery of public transport trips was likely higher as these segments have returned to work during GCQ.

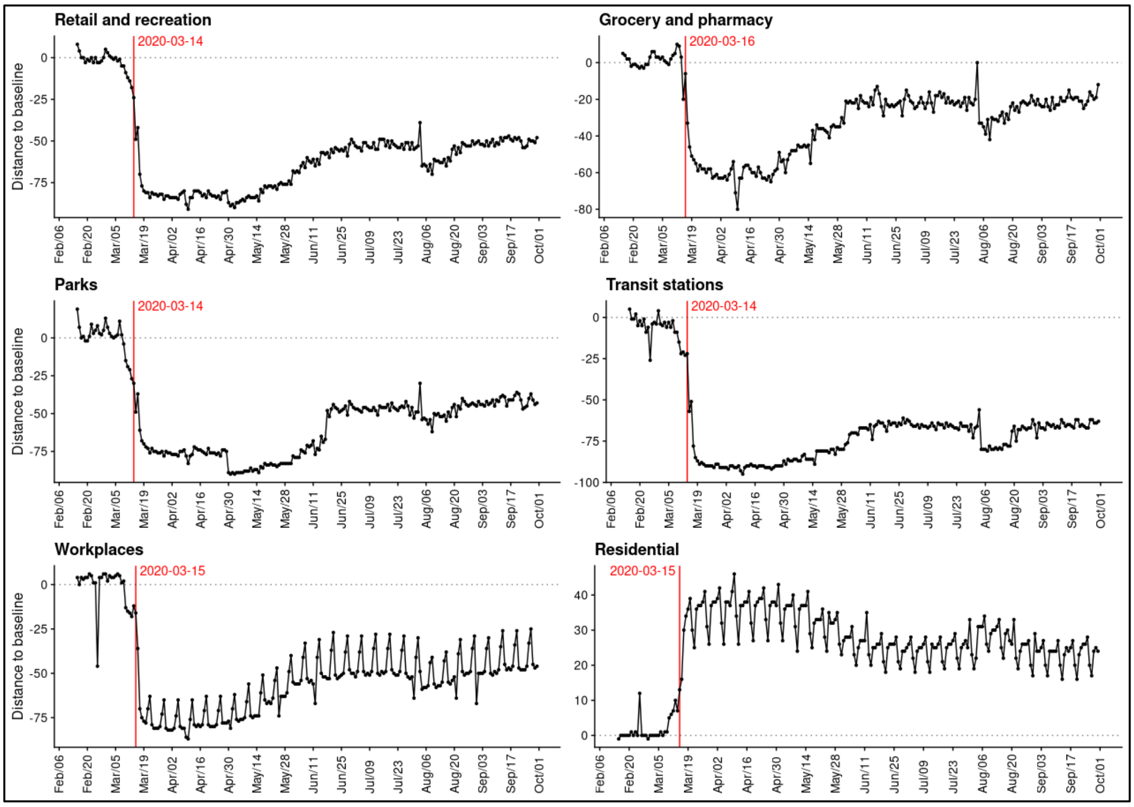


Figure 3.5. Changepoint in location patterns for Metro Manila

Time period: 2020/02/15 - 2020/09/30

Based on the Apple data, Figure *3.6* shows patterns of trip directions requests of the MM population by transport mode (*driving*, *transit*, *walking*) between January 13 and September 30. After the first local COVID-19 cases were reported, a decline in travel requests in all three categories can be observed more or less simultaneously and at a similar pace. While for *driving* the lowest level was reached on April 4 at -82.2, the *walking* category went down to -83.2 (April 4), and *transit* even to -85.1 (March 31). In the further course, however, it becomes apparent that the various categories recovered differently. The fastest recovery can be observed for *driving*, which reached about 50 % of the baseline level by the end of September (-49.6 on September 30). *Walking* initially recovered similarly. However, with the first introduction of the GCQ, it fell behind *driving* and then reached a similar level again by the end of the analysis period (-51.8 on September 30). We expect that the first increase in *driving* and *walking* mainly relates to essential trips (e.g., work, grocery, etc.) that were allowed during MECQ. Non-essential (leisure) trips during GCQ, instead, possibly rather relate to trips by car. Finally, *transit* lags well behind the other categories (-61.8 on September 30), mainly due to the lack of or reduced supply of services.

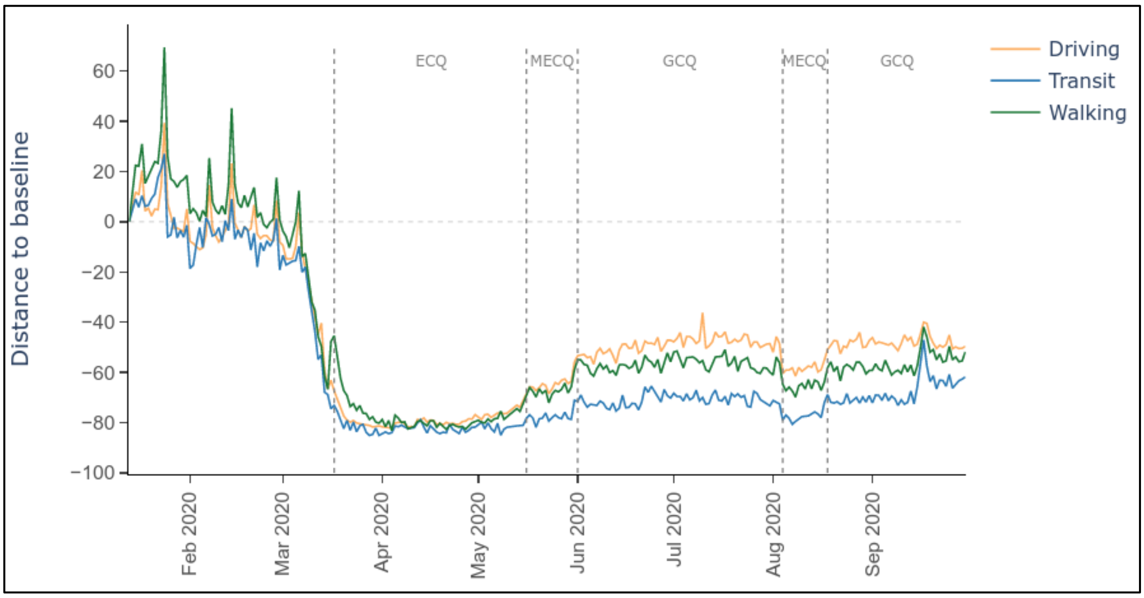


Figure 3.6. Apple trip patterns by transport mode in Manila (as of September 30, 2020)

In summary, the most important results of the above analysis of mobility data relate to the following.

(i) Mobility reduced during the lockdown period, with people spending more time at home, and significant reductions were observed with regards to all location report categories (most of all at transit stations).

(ii) The impact of the lockdown on mobility happened almost immediately – there was no gradual reduction, but there is a gradual increase through to the second MECQ period, when the containment measures were tightened again. After another drop, mobility activities then quickly returned to the previous level.

(iii) Driving and walking trips have seen less reductions and are recovering more quickly than transit trips.

3.5. Transport policy implications

The results of this study are reflected by far-reaching implications for the transport systems and citizens in MM. (1) Those who rely most on public transport and without access to private cars are disproportionately affected by the lockdown, which has intensified the unequal access to transport systems. (2) It became evident that during the pandemic, public transport was not able to fulfil its service function to the public and that (3) a paradigm shift was observed, as people increasingly relied on active mobility.

A comparison with other studies helps to put our results in context and gives additional insights.

For example, while car journeys in MM recovered relatively quickly, case study results from Istanbul, another developing megacity, point to the risk of an unsustainable development, in which private cars become the dominant mode of transport (Shakibaei et al., 2021). A large part of additional car journeys could thereby result from users that previously relied on more sustainable travel options such as mass transit, active mobility, and shared mobility solutions. Accordingly, Pawar et al. (2020) found that during the COVID-19 pandemic, 5.3 % of commuters in India shifted from public to private modes. To regain trust in public and shared modes, therefore, social attitudes and human factors need to be addressed more explicitly (Shokouhyar et al., 2021), while street space should be allocated to cyclists and pedestrians (Arellana et al., 2020).

Taken together, these findings provide valuable insights on how to respond to such altered situations. The following sub-sections therefore discuss policy implications – mainly related to transport planning, but also with relevance to urban planning and managing cities in general (Junior et al., 2021).

3.5.1. Promote active mobility and prioritize public transport (short-term)

The shutdown of public transport during the ECQ and the subsequent limitation of capacities particularly hit households without a car – which corresponds to 88.5 % of all households (JICA, 2015). As a result, many non-essential trips were avoided or could not be undertaken at all. There was often no other choice for essential trips than to walk or cycle, even for large distances. Various news articles reported of individuals, in many cases health workers, who had to travel countless kilometers and hours to get to work (e.g., Mercado, 2020). Also, news articles have increasingly been reporting on cyclists involved in fatal accidents with motorized vehicles (e.g., Tiangco, 2020), which exposes one of the main obstacles to choosing a bicycle as a means of transport. In 2019 alone, the Metropolitan Manila Development Authority (MMDA) recorded 1,759 bicycle related road accidents, including 19 fatalities (MMDA, 2019). Even though there are various other reasons (cultural, climatic, topographic, etc.) why there is historically a negligible share of cycling trips in the modal split of cities in the Philippines, the lack of safe and protected cycling infrastructure is striking. Therefore, rapid action is required to meet and enable the new demand for active mobility and to relieve public transport. Similar as observed in many cities around the globe, also in MM, temporary pop-up bike lanes emerged throughout the metropolis (Figure *3.7*). These bike lanes are effective in quickly dedicating road space and safety to cyclists. In this sense, pop-up bike lanes require a clear demarcation (ideally physical segregations such as construction site beacons, traffic cones, bollards) to motorized traffic as well as clear labeling and the monitoring of compliance. In addition, sufficient bike racks and other cycling-friendly facilities should be installed at common origin and destination locations (malls, workplaces, restaurants, transit hubs, etc.).

a) b)

Figure 3.7 (a + b). Pop-up bike lanes in Metro Manila along Ayala Avenue (left) and East Avenue (right)

Source: Hans Cecilio Bosshard (August 2020); Niño Jesus Orbeta (August 2020)

With regards to public transport, reduced capacities and other restrictions made short-term operational adjustments inevitable. The containment policies in MM required operators to enhance hygiene concepts and modify transport vehicles and stations to comply with physical distancing guidelines. While this is important in order to rebuild confidence in public transport, at the same time, it forfeits operational efficiency and places a severe financial strain on operators. As a countermeasure to such restrictions, policymakers have several options for prioritizing and making public transport services more attractive and viable. A widespread solution in times of the COVID-19 crisis, was to set up pop-up bus lanes and corridors. In MM, an interim BRT system began operations on July 1 along Epifanio de los Santos Avenue (EDSA), the metropolis' main north-south artery and most frequented road. The so-called EDSA Busway, which is segregated by concrete barriers and steel separators, runs along median lanes, and serves on fixed bus stops that are currently located on the curbside (Figure *3.8*). This service was established without fare increase and is expected to be a significant improvement over the prior bus model, as travel time along the EDSA stretch is expected to decrease from 2-3 hours to 45 minutes, including bus stops (Dela Cruz, 2020).

Financial viability of the public transport sector not only needs to be ensured to restore the livelihoods of transport workers, but also in the context of environmental targets. The COVID-19 pandemic has significantly hampered the transition to cleaner public transport vehicles in the Philippines, which was initiated by the government in 2017 through the Public Utility Vehicle Modernization Program (PUVMP) (Sunio et al., 2019). Own-account drivers of informal means of transport, who have purchased electric vehicles under loans and ran into financial difficulties due to reduced operations and the continued enforcement of occupancy limits[5], thus, require significant financial assistance (e.g., deferred loan payments) in order to keep the transition afloat.

a) b)

Figure 3.8 (a + b). The newly implemented EDSA Busway BRT in Metro Manila

Source: 'Jel' (June 2020); Jack Schmidt (October 2020)

3.5.2. Provide adequate infrastructure and reform of public transport (mid-/long-term)

The short-term wins described above, however, are pointless if not converted into long-term, sustainable successes. For long times, cycling in the Philippines was considered unviable, while infrastructure planning for active mobility has most commonly been absent due to the lack of regard for a holistic approach in urban transport planning. Therefore, it is important to leverage the current demand for active mobility and further promote safe and prioritized walking and cycling through the provision of adequate infrastructure. Studies suggest that active mobility infrastructure is a necessary condition for inducing a modal shift (Song et al., 2017). Hence, the temporary pop-up bike lanes should be transformed into permanent, protected bike lanes and integrated into a dense and

[5] This information is based on personal communication with Dr. Jose Bienvenido Biona, Executive Director of the Electric Vehicle Association of the Philippines (eVAP).

interconnected cycling network, complemented by extensive bike-sharing systems. Case study results from New York City show that bike-sharing systems have proven resilience over other transport modes and that increases in travel distance as well as modal shifts are observed in times of pandemics and during other disruptions (Teixeira and Lopes, 2020).

It is also essential to make the metropolis more pedestrian-friendly and consider walking as an actual mode and means of transport. In the current car-centric development in MM, road widening initiatives aimed at providing more and more car lanes, while only narrow spaces have been dedicated to pedestrians, which are often additionally restricted due to street vendors, on-street parking, and other hindrances. Thus, urban planning needs to put more focus on walkability, consider pedestrians' needs, including the elderly, and re-allocate road space to make walking and cycling safer and enable proper social distancing. Besides the recognized benefits of walking and cycling on our health, well-being, and the environment, also active mobility's economic benefits should be highlighted (Handy et al., 2014). Besides reduced health care and transport (infrastructure) costs, benefits derive as well from improved access to businesses (i.e., pedestrians and cyclists are more likely to visit local shops compared to car drivers), which in the current time is crucial for revitalizing the economy and supporting local businesses.

The COVID-19 pandemic has somehow indeed served to be an eye-opener to the Philippine Government on the importance of active mobility. On August 19, 2020, a Joint Administrative Order (2020-001) was issued by four executive departments of the Philippine government (including the DOHRP) on the "Guidelines on the Proper Use and Promotion of Active Transport During and After COVID-19 Pandemic". This was then followed by the issuance of Department Order 2020-88 by the Department of Public Works and Highways (DPWH) containing "Guidelines on Design of Bicycle Facilities along National Roads" on September 29. While these guidelines reflect positive transformations at the highest levels of governance, holistic and sustained efforts are needed in order to realize such transport systems transformations.

There is currently also an unprecedented opportunity to improve public transport through infrastructure investments and reforms. This pandemic has underscored the importance of public transport and the fact that the current regime is insufficiently performing its public service functions for the general public. Infrastructure investments and new concepts are thus required to meet demand and keep operations running efficiently despite reduced vehicle capacities. In addition to rail-based solutions (e.g., the MM Subway that is currently under construction), prioritized bus services on dedicated lanes (BRT) are required. Hence, the introduction of the EDSA busway was a logical step, but it urgently needs to be expanded in terms of adequate infrastructure and fitted into an extensive route network. Reforms of MM's public transport regime are also long overdue. The current commission-based model depends on private sector initiatives, where the main objective for bus operators is farebox maximization. Subsequently, uncoordinated supply and the passenger-striving behavior of buses significantly contribute to traffic congestion (in particular along EDSA), resulting in poor service quality and excessive travel times. Instead, a consolidation of operators and a centralized and holistic planning of the road public transport network could provide a remedy. At the same time, revenue models need to be reimagined. In order to guarantee high-quality bus operations despite reduced farebox revenue, services should be partially subsidized and tendered through service contracts (Chen et al., 2016).

In Resolution No. 69 dated September 7, 2020, the Inter-Agency Task Force for the Management of Emerging Infectious Diseases (IATF-EID) approved the implementation of service contracting and partial subsidies for public transport in the Philippines, to "incentivize operators, restore livelihoods of displaced transport workers, [and] empower the government to enforce health, safety, and operational standards […]." In addition to these mid-term objectives, indeed, the transition to service contracting could help make public transport more attractive in the long run, induce a modal shift, and increase the transport systems' operational efficiency and sustainability.

3.5.3. Leverage big data, digitalization, and MaaS for sustainable and resilient transport systems

Triggered by technological advances as well as societal and market changes, urban transport is currently experiencing a major transition. This has opened doors to NMS based on digital platforms – such as carpooling and ride-hailing – and eventually paved the way for Mobility as a Service (MaaS). MaaS is "based on the seamless integration of all different public and commercial modes of transport and is delivered via a digital interface. The service must enable multimodal travel possibilities and thus allow for the planning and booking of multimodal journeys, support on the go and payment as well as alteration of the planned journey" (EMTA, 2019). While MaaS is mainly on the rise in the global North (e.g., in Finland, Sweden, Germany, and the Netherlands), it is expected to diffuse quickly to developing countries as well (see Chapter 2). Moreover, the COVID-19 pandemic could accelerate its global uptake as MaaS could serve as a safe, phased reopening strategy for transport networks in cities worldwide (Singh Sehmi, 2020). Hence, initial MaaS trials and pilots are also at the planning stage in MM, including the EU-funded SOLUTIONSplus Project[6].

MaaS is a data-driven approach that builds on (public-private) collaboration and transport integration – all imperative ingredients to enhance situation awareness, strategic management, and resilience of transport networks in pandemic times and beyond. Cities and transport operators must work hand in hand to overcome unforeseeable challenges and respond to quickly changing situations. MaaS is a suitable setting to frame and foster these partnerships and collaborations. In MM and most developing megacities, this could be particularly valuable and challenging at the same time due to the highly fragmented and individualized operator landscape.

The MaaS platform bundles and combines different modes of transport to serve demand more efficiently. This also contributes to ensuring the mobility of citizens at any time and in any situation by not depending on a single transport mode (Megahed and Ghoneim, 2020). This is particularly crucial considering the significant effects of transport infrastructure on the aggregation of COVID-19 cases (Li et al., 2021). It is therefore important that the transport authorities embrace data sharing and open-source data, and support investments in ICT infrastructure. Accordingly, the National Transport Policy (NTP) and its Implementing Rules and Regulations (IRR) stipulate the "establishment and maintenance of an open database system for all government agencies […]". This is a basic requirement for responsive space management in both shared mobility and public transport. That is, vehicle capacities and passenger flows can actively be monitored and controlled using vehicle GPS, automatic passenger count systems, CCTV, or lower-cost community-based smartphone reporting schemes. If necessary, traveler flows can be actively steered to relieve routes and transport infrastructure in real-time.

On the demand side, providing real-time passenger and crowding information is more relevant than ever before, as it enables careful trip and route planning and off-peak commuting. If required, contagion warning systems based on anonymized data could warn users about possible contacts with infected persons. MaaS is a tool for directly combating COVID-19 for another reason as well, as it stipulates the integration of electronic/mobile ticketing and payment systems. Thus, it reduces the overall physical contact during the procurement of tickets and conducting payment transactions (especially in Jeepneys). The Department of Transportation (DOTr) and the Land Transport Franchising and Regulatory Board (LTFRB) are accordingly pushing for cashless transactions for public transport services and have recently issued several circulars and statements in this regard.

[6] http://www.solutionsplus.eu/partners.html

Ultimately, MaaS provides massive opportunities for the generation and utilization of much needed data not only for informing time-sensitive decisions for responding to such pandemics, but also for long-term transport planning and strategy building through which the transport systems can continuously be improved and optimized.

3.6. Research limitations and future research

The limitations of this research mainly relate to the data used in the study. More than two-thirds of the Philippine population are internet users, of which a large percentage either use the Google Maps or Apple Maps service (StatCounter, 2020). While the data samples should thus be demographic (age, gender, etc.) representative, they are not expected to be representative in socio-economic terms. More specifically, only the mobility behavior of tech-savvy individuals (that know how to manipulate the mentioned map services) is included in our data. On the other hand, important population groups are likely to be underrepresented, such as the lower-income segments (that often do not have access to smartphones and the internet). We further stress that the available data can only reflect the situations on the ground to a certain extent. First, we have no information on the underlying reasons for changes in mobility behavior. For example, have users avoided public transport out of fear of infection with SARS-CoV-2, because no service was available, or simply because there was no demand for traveling? Second, the use of paratransit services (e.g., motorcycle taxis) are likely not adequately represented in the data. In addition, we only have limited insight into data collection and processing of the data providers. An information bias can be expected due to the relatively low number of classification categories for trip purposes in the Google data (6 categories) and transport modes in the Apple data (3 categories). As described in Section 3.2.2, a discrepancy in relation to the reported COVID-19 cases is expected due to underreporting. The results should therefore be viewed with some caution, especially what concerns the analysis of the causality of measures and the occurrence of cases.

However, for the purpose of this study – being conducted with a broader macroscopic perspective – the authors expect these data limitations to have a minor impact on the overall study results, which we therefore expect to be a close representation of reality. Nevertheless, additional work at the microscopic level is recommended for a deeper understanding. It is important to zoom in to the perspective of individuals and different population segments to derive better insights into modal shifts and to better understand underlying reasons for changes in mobility behavior including whether they are of temporary or permanent nature. Eventually, this could strengthen the findings presented in this study and/or provide the knowledge for a more in-depth discussion on post-pandemic policy implications for developing megacities.

Other limitations relate to the study design and working with such rapidly changing subject. Based on observed changes in mobility behavior, we draw conclusions for a post-pandemic scenario for which we outline transport policy implications. Of course, this is associated with some uncertainty. For the transport policy implications, we rely on the analysis of quantitative data, without taking account for specific implementation challenges of transport interventions in developing countries or specifying its direct and indirect benefits and costs (Berg et al., 2015). While in this study – considering the scope of the journal – our focus is on sustainability standpoints, future research should analyze how the proposed policies can be implemented, however.

3.7. Conclusion

In this chapter, we identified and analyzed changes in mobility behavior in face of the COVID-19 pandemic. The data analysis shows that the changes are closely linked to the containment measures imposed by the governments. In fact, the different phases of the lockdown can easily be read from the data. During the strictest phase of the lockdown (ECQ), public transport was completely suspended and significantly restricted as the quarantine state continued over the following months. As a result, movements at transit stations fell by as much as 95 %, and public transport trips are the slowest to recover since then. This has particularly affected lower-income groups of the population, in particular, those without access to private cars. Thus, we demonstrate that another dimension of social exclusion, arising from the COVID-19 crisis, relates to transport and human mobility. This made immediate action by policymakers inevitable. In this article, three transport policy implications – addressing existing transport problems and the exposed lack of transport equity in both the short and long term – have been outlined and discussed.

The question of if and how these policies will be implemented have a significant impact on how the “new normal” for mobility will emerge. We argue that the opportunity to be seized is to anchor the choice of greener transport modes and a more sustainable mobility behavior within this new mobility paradigm. Our case study of MM shows that the national government agencies are taking initial steps in this direction and indeed are formulating strategies to build back better mobility. As a metropolis that has historically neglected sustainability (and thus, general resilience) in urban transport as a priority, this represents a long and arduous transition. In terms of exposing the otherwise unrevealed risk profile of such megacity (and the accompanying governance systems), the MM case therefore serves as an impetus for other developing megacities to set the right priorities and take appropriate actions.

Chapter 4

4. Towards sustainable transport in developing countries: preliminary findings on the demand for Mobility as a Service (MaaS) in Metro Manila

4.1. Introduction

Many countries of the developing world are greatly affected by mobility problems induced by prevailing global mega trends such as population growth and urbanization (Detter, 2015; Hayashi et al., 2004). In the Philippines, the National Capital Region – also referred to as Metro/Metropolitan Manila (MM) – is experiencing what in the media is frequently described as a 'transport crisis'. In this 13-million population metropolitan area, urban sprawl, lack of coordinated transport policies at the Metropolitan level, absence of adequate infrastructure and mass transit solutions, and rapid pace of motorization, amongst various other reasons, have led to an inefficient transport system which continuously collapses under growing demand (Andong and Sajor, 2017). As is common in large developing cities, this resulted in premature traffic congestion, deterioration of the environment, safety and security issues, and declining mobility of the poor (Gwilliam, 2003).

With traffic jams and gridlocks currently belonging to the region's everyday picture, a recent report by the Asian Developing Bank ranked MM as the most congested developing Asian city (ADB, 2019). Based on comprehensive navigation system data for 2019, MM even experienced the second highest daily congestion worldwide (TomTom, 2020). Logically, this situation has led to increased calls for transport reforms and changes in mobility behavior, which are urgent also for environmental reasons.

Indeed, transport and human mobility play a crucial role in the current climate debate (Wynes and Nicholas, 2017). We are currently experiencing widespread protests around the world as part of the 'Fridays for Future' movement with millions of people demonstrating for more climate action. During the global climate strike on September 20, 2019, the organizers counted 260,000 people in New York

City, 230,000 people in Berlin, and 120,000 people in Melbourne. Their concerns and call for a rapid reduction of GHG emissions are supported by the majority of the scientific community who for a long time have warned about the threats of global warming (Hagedorn et al., 2019, Ripple et al., 2019). As part of that, it has led large parts of the general public to understand that we need to fundamentally change behavioral and consumption patterns. Taking into account that the transport sector is one of the largest GHG emitters worldwide and that transport-related energy use continues to grow faster than any other sector (IEA, 2019; IPCC, 2014), this also refers to our travel habits. Consequently, sustainable transport has not only become a major domain in academic research (e.g., Gillis et al., 2016; Greene and Wegener, 1999), but also a frequent subject in the public discourse.

While these developments have mainly been observed in the global North, elsewhere the status quo differs significantly (Lee et al., 2015). In the Philippines, for example, it appears that climate change has not yet appeared as a crucial topic on the public agenda (Franzen and Vogl, 2013; Reyes, 2014) even though more environmental and sustainability awareness are imperatively needed. Not only is the Philippines currently one of the countries suffering the most from climate hazards (IEP, 2019), but it is also one of the countries most affected by the projected sea-level rise in the future (Kulp and Strauss, 2019). Cities that are located on the coastline are highly vulnerable and could face drastic consequences (Meerow, 2017). Considering a relatively conservative scenario of expected changes in global carbon emissions, by 2050 large parts of MM are expected to be permanently threatened by inundation[7].

A potential solution often promoted by academic researchers and policymakers to tackle both transport and environmental problems is the shift towards more efficient/sustainable transport modes (e.g., Creutzig et al., 2012; Nykvist and Whitmarsh, 2008). In this context, several policy directions have been suggested and implemented. They encompass measures such as restrictions, bans, taxation, pricing and subsidization, information campaigns to create awareness, and integrated transport and land-use planning. They also encompass the improvement of services as well as the provision of adequate infrastructure (e.g., Banister, 2008; Hayashi et al., 2004; Pojani and Stead, 2015). We would like to emphasize the role of the last types of measures, given their historical contribution to the diffusion of transport systems (Leibowicz, 2018) and the results of case studies, for example, on biking infrastructure (Marqués et al., 2015) and BRT systems (Wright and Fulton, 2005). Simply put, this means that providing the necessary infrastructure and improving services precede and stimulate the change of mobility behavior.

[7] We are referring to the Coastal digital elevation model (CoastalDEM) estimation by Kulp and Strauss (2019). A map for the area in MM threatened by inundation can be generated with the Climate Central's Coastal Risk Screening Tool available at https://coastal.climatecentral.org.

MaaS is a promising new transport solution that, according to first results from field tests and studies in developed countries, could follow a similar rationale. For example, during a 6-months MaaS field trial in Sweden, it has been found that "over time the participants became less positive towards private car and more positive towards alternative modes" (Karlsson et al., 2016, p. 3269). As such, many users of the service called *UbiGo* changed their mobility behavior and increased the usage of bus/tram (50 % of participants) or bicycle sharing (23 % of participants), while 48 % claimed to have used private cars less frequently than prior to the trial.

For this study, we collected online survey data in the Philippines from residents and commuters in MM. The questionnaire surveyed respondents' mobility-related and socio-demographic characteristics. Two binary response models have been specified with the objective to investigate preliminary demand for MaaS in developing countries and how it differs compared to findings in developed contexts.

Specifically, we have addressed the following research questions:

- (RQ1) How strong is the willingness to use MaaS in developing countries? Who are the potential adopters and what are their motives to use MaaS?
- (RQ2) By integrating different transport services and making them accessible on demand, does MaaS have the *potential* to promote a shift towards public transport and more sustainable mobility in developing countries?

This chapter complements the emergent literature on MaaS adoption and explores MaaS' potential beyond the developed world. Developing countries – which are home to the majority of the world's population, are growing rapidly, and often face severe transport-related problems – have so far been overlooked in existing studies. By focusing on a megacity that presents many of the prevalent transport characteristics in developing countries, this study offers first insights into MaaS in the context of the developing world – which we consider a promising field of research.

The remainder of this chapter is structured as follows. Section 2 provides the background for this study. Our research methods are presented in Section 3 and the study results in Section 4. We discuss policy recommendations in Section 5. Finally, Section 6 presents concluding remarks and an agenda for future research.

4.2. Background

4.2.1. Mobility as a Service (MaaS)

MaaS is a very recent concept. While a universal definition has yet to be developed, in the most prevalent view, it describes a new transport solution that integrates public and private transport services from different transport operators and service providers on a single platform (Jittrapirom et al., 2017).

MaaS springs from the 'Everything as a Service' (XaaS) paradigm, a huge stream known from cloud computing, where products, processes, data, information, and so forth, are being provided as a service (Duan et al., 2015). It thus translates the XaaS-concept into the context of transport, by promoting a shift from buying/owning means of transport towards servitized transport modes.

The MaaS concept originates from Finland where – since Hietanen (2014) – it has been strongly pushed and promoted by public and private actors. Nowadays, it is a widely used term in the scientific and grey literature comprising several publications by academic researchers (for recent reviews, see Calderón and Miller, 2019; Utriainen and Pöllänen, 2018), government agencies (e.g., Finnish Transport Agency FTIA, Transport Committee - UK Parliament, Dutch Ministry of Infrastructure and Water Management, and Swiss Federal Office of Transport BAV), international organizations (e.g., ITF/OECD, UNECE), research, tech, and consulting firms (e.g., Accenture, Cisco Systems, Deloitte, KPMG), and interest and industry associations (e.g., AARP, EMTA, IET, UITP) – pointing to its expected impact and market potential (see **Fehler! Verweisquelle konnte nicht gefunden werden.** for a comprehensive list of MaaS white papers and reports).

While integrated transport has been a goal of transport authorities for decades, MaaS leverages recent developments in digital technologies as well as societal changes such as the sharing economy to bring this idea into reality. MaaS incorporates NMS such as ride-hailing and car- and bike-sharing, makes services accessible on demand and on a single payment channel, and converts them into so-called mobility packages (also MaaS plans, mobility plans, or bundles) (Jittrapirom et al., 2017).

As the number of MaaS schemes and trials are rapidly increasing, it remains a difficult task to frame and categorize relevant MaaS providers. We note that the presumed MaaS schemes differ greatly in terms of BMs, service features, and the number and types of integrated transport modes. One way to classify them refers to the degree of integration (Kamargianni et al., 2016; Sochor et al., 2018).

Here, a distinction is made between partial/advanced integration and a classification based on integration levels ranging from 0-4 (Table *4.1*).

Table 4.1. Typology of MaaS schemes according to the level of integration

Integration Categories (Kamargianni et al., 2016)	Integration Levels (Sochor et al., 2018)	Examples
-	4 - Integration of societal goals	
Advanced Integration with mobility packages	3 - Integration of service offers (bundles)	Whim, UbiGo (pilot)
Advanced Integration	2 - Integration of booking & payment	Free2Move, moovel, Jelbi
Partial Integration	1 - Integration of information	Moovit, Qixxit, Google maps
-	0 - No integration	Lyft, Hertz

There are several operating MaaS schemes in different parts of the world that fall under the advanced integration category or the MaaS level 2 type/class, respectively, including *Free2Move*[8], *moovel*[9], and *Jelbi*[10]. However, to the authors' best knowledge, the only provider offering advanced integration with mobility packages (or MaaS level 3) is the Finnish start-up *MaaS Global*. Its service *Whim*[11] has been officially launched in the Helsinki region in November 2017. Meanwhile, they have expanded internationally, for example, to Birmingham/West Midlands (UK), Antwerp/Flanders (Belgium), and Vienna (Austria).

Due to the limited number of real-world applications, several scientific studies have focused on (possible) implications as well as conditions for MaaS in the context of selected regions and countries – mainly in the developed part of the world. They include the Alpine regions (Signorile et al., 2018), the UK (Enoch, 2018), Germany (Hasselwander, 2019), Australia (Mulley et al., 2020), and the application of MaaS in rural areas (Eckhardt et al., 2018, Geurs et al., 2018).

The scientific community perception of the potential of MaaS to solve transport-related problems is rather positive. However, many studies consist of reviews, theoretical discussions, and qualitative studies. Possibly because of the novelty of MaaS and the paucity of available data, few studies provide empirical evidence about MaaS (expected) market potential, outcomes, and benefits.

[8] https://us.free2move.com/app
[9] https://www.moovel.com/en/our-products/for-public-transit-agencies-operators/mobility-app
[10] https://www.jelbi.de/
[11] https://whimapp.com/

Many of the available quantitative studies so far have addressed the potential users of a MaaS system mainly through stated choice/preference analyses (Table *4.2*). A central issue of these articles refers to mobility packages and the question of how to bundle services, which is therefore obviously considered as a relevant leverage point for MaaS providers. Guidon et al. (2020) found that once public transport is offered in a bundle, it is valued higher compared to when valued individually. Matyas and Kamargianni (2019), in addition, highlight mobility packages' potential to introduce users to services they have not used before. Together with the results from the *Ubi-go* trial (Karlsson et al., 2016; Sochor et al., 2016) these findings therefore support the idea that MaaS could loosen people's reliance on private cars and increase the use of more sustainable transport modes (i.e., public transport and shared services). Notwithstanding, other studies leave some doubt as to whether MaaS can appeal to avid car users (e.g., Alonso-González et al., 2020; Fioreze et al., 2019; Ho et al., 2020).

A study commissioned by *Maas Global* examined the outcomes and effects of *Whim*'s first year of operation. Its results indicate that *Whim* increased the use of public transport and promoted intermodal travel, and that the integration of NMS enabled the substitution of private car trips (Ramboll, 2019). Other attempts to quantify outcomes and benefits of MaaS have been conducted through agent-based simulation. Djavadian and Chow (2017) used data from Oakville, Ontario (Canada) to model MaaS as a solution to tackle public transport's first/last mile problem at a train station. Results from a case study of the Greater Zurich area, Switzerland suggest that the integration of various transport services leads to efficiency gains and reduction of energy consumption (Becker et al., 2020). Kamargianni et al. (2019), in addition, have proposed a framework to simulate the entire MaaS ecosystem incorporating the decision makers and the interaction of involved stakeholders in the short- and long-term. The application of this framework could deliver first insights on the long-term impact of MaaS on transport systems and user behavior.

However, many of the aforementioned findings are likely not transferable – or are transferable only to a certain degree – to the context of developing countries, considering significant variations in available transport infrastructure and citizens' travel behavior (Gwilliam, 2003).

Indeed, the literature in the context of developing countries is yet incipient. Singh (2020) reports insights from the *Kochi One*[12] scheme in Kochi, India, and the city's transition towards MaaS which provides preliminary evidence about the feasibility of MaaS in developing countries. Adjustments to the MaaS model in Kochi involve the use of smart cards (along with the Kochi One app) and the integration of informal transport services. In the context of Phuket, Thailand Khaimook et al. (2019)

[12] https://kochimetro.org/kochi-1-card/

studied the potential of MaaS not only to contribute to more efficient and sustainable transport, but also to increase road safety. They concluded that MaaS, indeed, can break travel habits and encourage people to make safer travel choices (e.g., using public transport instead of traveling by motorcycle).

Nevertheless, little is known about potential users' intentions and preferences and how MaaS can be established in developing countries. The success and rapid diffusion of ridesharing and other internet-enabled services provides an analogy that underlines the potential and demand for NMS (including MaaS) in the developing world. Several case studies found that socio-demographic characteristics – such as age and income level – are decisive adoption factors in developing contexts (e.g., Acheampong et al., 2020; Lesteven and Samadzad, 2021). Experience from ride-hailing, moreover, provides evidence for the mode-substitution effect of NMS (Tirachini, 2019).

However, with public transport trips often being substituted, it is argued that many NMS rather increase negative transport externalities and do not contribute to a sustainable transition in developing cities (Suatmadi et al., 2019; Tirachini, 2019).

With regards to implementing MaaS in developing cities, the literature suggests that the translation of transport policies settings – especially from a developed to a developing context – remains a difficult task (Canitez, 2020). Pojani (2020) argues that rather than policy transfer, putting the acquired knowledge into practice and implementing it locally is the critical step. This would require the consideration of local socio-cultural heritage, traditions, and citizens preferences, amongst others (Sharmeen et al., 2021).

Hence, the lack of insights regarding demand side peculiarities in the developing world causes a significant knowledge gap in the MaaS literature, also leaving many issues for policy and practice unanswered.

Table 4.2. Overview of literature on MaaS adoption

Article	Authors	Year	Case study	Research method	Main findings
Developing the 'Service' in Mobility as a Service: experiences from a field trial of an innovative travel brokerage	Karlsson et al.	2016	Gothenburg, Sweden	Mixed-methods approach based on field test (trial)	Participants of the trial reported decreases in private car use and increases in alternative mode use (particularly car sharing and public transport).
Trying out mobility as a service: Experiences from a field trial and implications for understanding demand	Sochor et al.	2016	Gothenburg, Sweden	Mixed-methods approach based on field test (trial)	Participants reported curiosity as the main motivation to adopt MaaS.
Potential uptake and willingness-to-pay for Mobility as a Service (MaaS): A stated choice study	Ho et al.	2018	Sydney, Australia	Stated preference survey data analysis	Car non-users and infrequent users are most likely to adopt MaaS. However, frequent car users seem to be interested in subscribing to mobility packages.
Public preferences for mobility as a service: Insights from stated preference surveys	Ho et al.	2020	Tyneside, UK	Stated preference survey data analysis	Young smartphone users are likely to adopt MaaS. MaaS could be a substitute for the second household car, but not the only car in the household.
The potential of mobility as a service bundles as a mobility management tool	Matyas and Kamargianni	2019	Greater London, UK	Stated preference survey data analysis	Users, particularly those with lower household incomes, prefer mobility packages that include public transport.
Mobility as a service in community transport in Australia: Can it provide a sustainable future?	Mulley et al.	2020	NSW and Queensland, Australia	Stated choice experiment with survey data	The willingness to pay for bundled mobility services are substantially lower than the unit costs of provision.
Exploring motivational mechanisms behind the intention to adopt mobility as a service (MaaS): Insights from Germany	Schikofsky et al.	2019	Germany	Partial least squares analysis with qualitative interview data	Psychological needs play a crucial role in the acceptance of MaaS, such as anticipated advantages of autonomy, competence, and the feeling of being related to a social peer group.
Transportation service bundling–for whose benefit? Consumer valuation of pure bundling in the passenger transportation market	Guidon et al.	2020	Zurich, Switzerland	Discrete choice experiment with survey data	Transport services offered in a bundle may increase (e.g., public transport, car sharing) or decrease (e.g., bicycle sharing, taxi) its perceived value compared to the stand-alone service.
Bundling, pricing schemes and extra features preferences for mobility as a service: Sequential port-folio choice experiment	Caiati et al.	2020	Netherlands	Sequential portfolio choice experiment	The price of the monthly subscription is a key adoption factor. Public transport is the most preferred mode for bundles.
On the likelihood of using Mobility-as-a-Service: a case study on innovative mobility services among residents in the NL	Fioreze et al.	2019	Netherlands	Mixed-methods approach based on survey/focus group data	Residents show a significant interest in trying out MaaS but are not likely to use it in the long run. Unlike demographics, attitudes (e.g., environmental awareness) determine adoption of MaaS.
Drivers and barriers in adopting Mobility as a Service (MaaS)–A latent class cluster analysis of attitudes	Alonso-González et al.	2020	Netherlands	Latent class cluster analysis of attitudes	The cluster of individuals with multimodal weekly mobility patterns is most likely to adopt MaaS.

4.2.2. Case study presentation: Metro Manila

The Philippines is an archipelagic country in Southeast Asia with a population of well over 100 million. Ranked by the World Bank as a lower-middle income country, it is one of the fastest growing economies in the world. MM, located on the island of Luzon in the Northern part of the country, represents the Philippines’ center of culture, economy, education, and the seat of government. It comprises 16 cities and one municipality, and occupies an area of about 620 km² (Figure *4.1*).

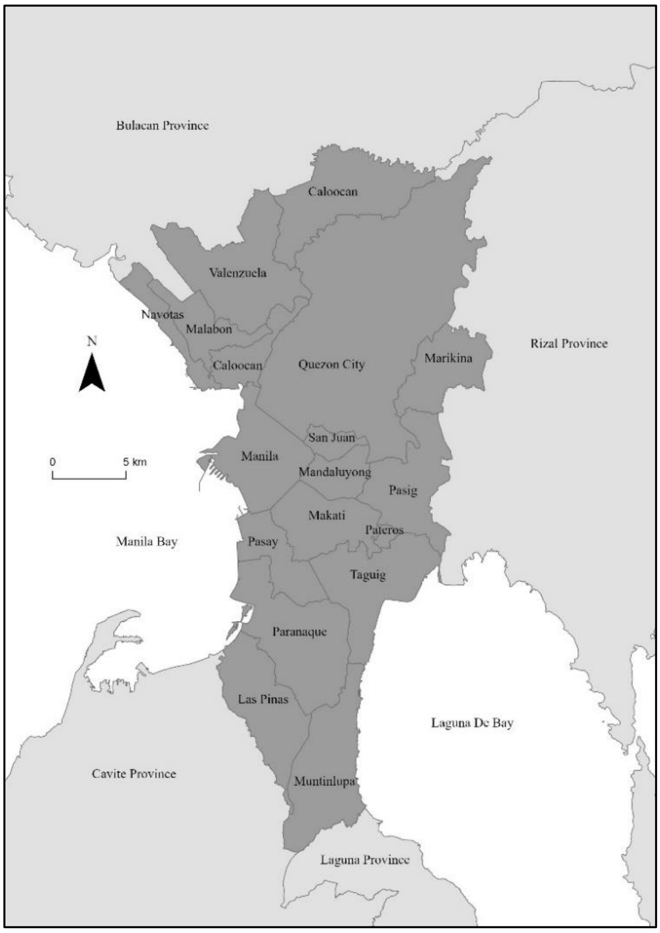


Figure 4.1. Map of Metro Manila (dark grey) and its adjoining provinces (light grey)

Outside the map section but part of the study area: Pampanga Province in the north and Batangas Province in the south of the metropolitan area. [Data from PhilGis.org]

The urbanization process, however, has spilled out of MM borders into the adjoining provinces (also referred to as Mega Manila) from which a huge number of common trips are generated. With a population of around 13 million (and a daytime population reaching up to 15 million), MM is one of the most crowded and dense urban areas in the world. According to the latest census data from the Philippine Statistics Authority (PSA), the population is very young (in 2010, 58.9 % were younger than 30 years) and growing extremely fast (1.58 % annually during the period 2010-2015).

In MM, vast social and spatial inequalities are observed, as well as an increasing gap between rich and poor. This development can be read off by a comparison of the current urban transformation with, at both extremes, locally disembedded wealthy enclaves on one side and low-income, informal settlements on the other (Kleibert, 2018). Also, citizen's mobility characteristics and travel behavior are very diverging (Hickman et al., 2017). Abad et al. (2019) found that low-income neighborhoods in the periphery lack adequate access to transport services, while locations with high housing prices (e.g., in proximity to the CDBs) provide the best accessibility. In addition, Andong and Sajor (2017) highlight a long-term trend that employees move farther away from their workplaces and that commuting distances are increasing accordingly. Vehicle ownership in MM, according to Rith et al. (2019), correlates to socioeconomic characteristics and land use patterns. Given the positive impact of income on car/vehicle ownership and motorization (Dargay and Gately, 1999; Kutzbach, 2009), it is not surprising that rising per capita income in recent years has boosted private car sales in MM. Unlike in most Western countries, however, the private car is not the most dominant transport mode in MM. In fact, its modal split share is still relatively low (20.4 %) (JICA, 2015) and yet accounts for 72 % of road traffic (NEDA, 2014). Due to the rapid pace of motorization and declining occupancy levels, car trips have increased by 69 % between 1996 and 2012 (NEDA, 2014). Nevertheless, 88.6 % of households do not own a car. More than two-thirds of the estimated 12.8 million daily trips in MM are, therefore, made by public transport (NEDA, 2014). According to different classification frameworks, there are numerous developing cities around the globe with similar transport characteristics and conditions to MM (Table *4.3*).

Table 4.3. Transport- and mobility-related city typologies and categorizations

Framework	Variables/Indicators	Comparable Cities to MM [Category]
Categorization of City Circumstances (Gwilliam, 2002)	Income (Motorization); Size and size distribution; Political history; Population growth rates	Bangkok, Hong Kong
Global urban typology framework for sustainable mobility futures (Oke et al., 2019)	Metro propensity; BRT propensity; Bikeshare propensity; Development; Sustainability; Population; Congestion; Sprawl; Network density	Bangalore, Delhi, Dhaka, Lagos, Lahore, Karachi, Kinshasa, Kolkata, Pune, etc. [Congested Boomers]
Megacity Clusters (Priester et al., 2013)	General city characteristics; Transport supply indicators; Mobility indicators	- [MM identified as an outlier]
Urban Transport Development Paths (Barter, 2004)	Ownership of passenger modes; Urban mobility level	Bangkok, Jakarta [Traffic-saturated bus cities]

The public transport system in MM includes buses (regular and P2P buses), jeepneys (a country-specific paratransit service – the cheapest and most popular mode of transport in the Philippines), UV Express (a point-to-point service with air-conditioned utility vehicles), a rail transit network with three lines (LRT1, LRT2, MRT3), and a commuter rail line (PNR Metro Commuter Line). In addition, more than 21,000 taxis ply the streets of MM, while tricycles (the local auto rickshaw version operated as shared taxis or private hire) and pedicabs (non-motorized three wheelers) are readily available as first/last mile options.

Shortly after the launch of the first TNCs in MM in 2014, the Philippines' government created a regulatory framework for these companies to legally operate in the country. Since then, several internet-enabled ridesharing services (i.e., taxi-hailing, ride-hailing, and carpooling) gained great popularity. *Grab*[13], the leading TNC in Southeast Asia, for example, claims that it occupies 60,000 active driver-partners in the country and that one out of six Filipinos has installed the *Grab* app (Grab, 2019). Yuana et al. (2019) explain that the insufficient provision and access to public transport in MM forces commuters towards the use of ridesharing services, which in turn increases private vehicle utilization and traffic congestion.

The overall transport system in MM, with a railway network of only 75.2 km and a road network operating at capacity limit, is considered very inefficient and not able to accommodate the citizen's mobility needs. Thus, several measures have been implemented and even more proposed to ease the metropolis' transport woes (Boquet, 2013). Many of these measures center around EDSA – the main north-south artery and most important and frequented road in MM. Aiming to reduce the number of cars on the streets, the Unified Vehicular Volume Reduction Program (UVVRP) came into force in 1995. This program, also known as 'number coding', bans certain vehicle types (based on the last digit of the license plate) from EDSA and other major public roads at certain times. In 2018, MMDA proposed the implementation of a high-occupancy vehicle (HOV) lane, which after a short trial phase, however, has been discarded. Other policies target buses, which – while striving for passengers along EDSA – contribute to traffic congestion. In this context, the 'Yellow Lane Policy', which allows buses to occupy only certain lanes, and the ban of provincial buses have recently been tested on EDSA.

Other attempts refer to the construction and expansion of transport infrastructure, particularly as part of the current administration's 'Build! Build! Build!' infrastructure plan. This includes the Metro Manila Subway and the Southeast Metro Manila Expressway projects as well as the LRT1 Cavite extension and other projects aiming to increase the transport system's overall capacity.

[13] https://www.grab.com/sg/

In addition to planned short-term improvements and longer-term infrastructure projects, increasing the efficiency of the public transport system could provide a remedy (Batalla, 2005). MM currently lacks a centralized and holistic plan for the road public transport network. The operator landscape is very fragmented. Buses, jeepneys, and tricycles are all privately owned and operated without subsidies. The provision of services depends on private sector initiatives and is not subject to any quality control, while franchises are issued in a rudimentary manner without considerations of road capacity constraints or changes in demand. These conditions result in a poorly managed public transport system with inadequate intermodal integration, high transport-related GHG emissions, and major traffic safety concerns. Operators have established competitive practices that disrupt vehicle flow, while commuters complain about declining service levels (increasing waiting and travel times, overcrowded means of transport, train breakdowns, etc.) and political failure.

Parallel to the ongoing PUVMP (Sunio et al., 2019), institutional and regulatory reforms could address the lack of rationalization and planning. The DOTr commissioned the Metro Manila Road Transit Rationalisation Study completed in 2014. Research initiatives such as the government funded PUBFix[14] project, in addition, propose optimal schedules, routes, and integration schemes for public transport.

4.3. Research Methods

4.3.1. Survey design

With support from the University of the Philippines - National Center for Transportation Studies (UP-NCTS), we conducted a small-scaled pre-survey with face-to-face interviews on two days in January 2019 at the Mall of Asia in Pasay City, MM. We used the inputs of the small sample to identify weaknesses regarding the formulation and comprehensibility of our questions as well as the response options to improve the survey design.

The final survey has been conducted online. Online surveys have become a popular tool for researchers from different scientific areas, including the field of transport research, as well as for different study purposes. Compared to other survey methods (e.g., face-to-face interviews and

[14] http://pubfix.transfix.ph/about.php

telephone surveys), their cost advantage and time saving benefits, the opportunity to address respondents from distant locations, as well as lower socially desirable responding bias are pointed out (Lindhjem and Navrud, 2011). On the other hand, uncertainty over the validity of the data and sampling issues remain as common shortcomings (Ilieva, 2002). This also applies to our study, as we discuss in more detail in Section 4.3.4.

The questionnaire was created using the Google Forms tool and disseminated online on popular social network platforms (i.e., *Facebook*, *LinkedIn*). We used a convenience sampling and snowballing technique: during a research stay of the first author at the UP-NCTS, the survey link was shared in social media networks and respondents were asked to share it with their contacts. The survey targeted respondents residing within MM (relating to 87.4 % of the sample) or living in one of the adjoining provinces and commuting regularly to MM (e.g., for work or school) (12.6 %). Answers have been accepted between February and July 2019, resulting in a total of 238 completed questionnaires.

4.3.2. Variables and data

The final questionnaire included a total of 20 questions. It first addressed transport- and mobility-related characteristics such as the number of available cars/motorcycles in the household (Table *4.4*). We also surveyed the total distance and time the respondents have traveled on the previous day. We deliberately referred to the previous day, which we expected to be easier to answer rather than asking for abstract typical or average travel distances and times. While this could potentially bias the observed modes, we note that the mode distribution in our data set is comparable to the numbers that are reported in a recent large-scale transport study in MM. That is, about half of all trips in MM are covered by public modes, followed by walking (about 30 %), and private modes (about 20 %) (JICA, 2015). With the same rationale, we asked about the respondent's last trip (instead of a typical trip) and the number of required transfers (considering the use of public transport even if the respondent used other modes). In order to record the degree of multimodal travel behavior, we asked which types of transport modes the respondent is using regularly (i.e., at least once a week). Finally, we also asked the respondents for the factors they valued most when choosing a transport mode for a trip (e.g., the availability of travel information[15]) as well as their main trip purpose.

[15] Note that in the Philippines, public transport is mostly informal, without timetables and detailed route information available. On the other hand, internet-enabled alternatives such as ride-hailing provide detailed information on travel and arriving times.

Table 4.4. Descriptive statistics for respondent's transport- and mobility-related characteristics (N=238)

Variable	Description (Measurement and value)	Category	Observations (percentage)	Mean (SE)
RESID	Respondent's residence (=1 if he/she resides in MM, otherwise = 0)	-	203 (87.4)	-
HCARS	Number of cars available in the household	-	-	1.27 (1.42)
HMOTOS	Number of motorcycles available in the household	-	-	.42 (.86)
MODES	Number of different transport modes used at least once a week	-	-	3.42 (2.09)
PRICE	Factors that determine respondent's	Price/Costs	148 (62.2)	-
TIME	transport mode choice. Respondents	Time	179 (75.2)	-
COMFORT	could select up to three *unweighted*	Comfort	129 (54.2)	-
SAFETY	factors.	Safety	99 (41.6)	-
TRAVELINFO	(=1 if the respondent chose the	Avail. Travel Info.	20 (8.4)	-
ENVIRON	respective factor, otherwise = 0)	Environm. impact	5 (2.1)	
RELIABILITY		Reliability	40 (16.8)	-
TRIPS-PV	Number of single trips per transport	Private vehicle	-	.99 (1.47)
TRIPS-PT	mode made on the *previous* day	Public transport	-	1.15 (1.34)
TRIPS-TX		Taxi	-	.15 (.60)
TRIPS-RH		Ride-hailing	-	.63 (1.15)
TRIPS-SM		Soft modes	-	1.33 (1.60)
TOTDIST	Total distance in km traveled on the	[1] <15	107/12 (50.0)	-
	previous day (business day/weekend)	[2] 15-35	73/11 (35.3)	-
	(1-4)	[3] 36-55	16/3 (8.0)	-
		[4] >55	15/1 (6.7)	-
TOTTIME	Total time in hours spent traveling on	Business day	-	2.36 (1.67)
	the *previous* day (continuous variable)	Weekend		2.55 (1.53)
WORK	Main purpose for the last trip made	Work/School	176 (73.9)	-
BUSINESS	(=1 if the respective trip purpose is the	Business	31 (13.0)	-
FF	respondent's main trip purpose,	Family/Friends	12 (5.0)	-
PERSONAL	otherwise = 0)	Personal	13 (5.5)	-
SHOPPING		Shopping	6 (2.5)	-
TRANSFERS	Number of transfers required for the *last* trip	-	-	1.13 (1.29)

In addition, we surveyed the respondents' socio-demographic characteristics as summarized in Table *4.5*. This also covered smartphone availability and whether the respondents had any transport applications installed on their mobile device. We assume that when respondents are already using a similar app (e.g., a ride-hailing or carpooling app), it is more likely that they would use a MaaS app as well.

The questionnaire included a written explanation of the MaaS concept, an explanatory image (Figure *4.2*) and a link to a short video[16] about MaaS. It described an app that would suggest the best (multi- and intermodal) travel alternative and would also provide real-time travel information before and during the trip. It also explained that all available transport modes and services would be included, and that it would only require a single payment for the entire journey. Moreover, it referred to the possibility of subscriptions and to pre-purchase limited or unlimited services on a monthly basis (mobility packages).

Table 4.5. Descriptive profiles of the sample compared with Metro Manila census data

Variable	Description	Sample (N=238)	Metro Manila*
SEX	Male	.46	.49[a]
	Female	.54	.51[a]
AGE	Age Group		
	-Under 20	.04	.39[a]
	-20-29	.58	.20[a]
	-30-39	.24	.16[a]
	-40-49	.08	.12[a]
	-50-59	.03	.08[a]
	-60 and above	.03	.06[a]
EDU	Highest education		
	-No Grade Completed	.00	.00[c]
	-Elementary	.00	.09[c]
	-Highschool	.06	.44[c]
	-College	.75	.42[c]
	-Post Secondary	.19	.05[c]
OCCUP	Occupation		
	-Student	.21	n/a
	-Working (full-time)	.68	n/a
	-Working (part-time)	.04	n/a
	-Unemployed	.03	n/a
	-Retired	.02	n/a
	-other	.03	n/a
HINCOME	Household annual income		
	-less than 40,000	.05	.00[b]

[16] https://www.youtube.com/watch?v=WXkJSppY5XU

	-40,000 – 59,999	.07	.00[b]
	-60,000 – 99,999	.08	.00[b]
	-100,000 – 249,999	.18	.14[b]
	-more than 250,000	.61	.85[b]
HSIZE	Household size	4.4	4.1[b]
PHONE	Smartphone availability	.99	n/a
APPS	Number of transport apps	1.4	n/a
	Sample size	238	12,877,253[b]

*Source: PSA; a Data from 2010; b Data from 2015; c Data from 2016

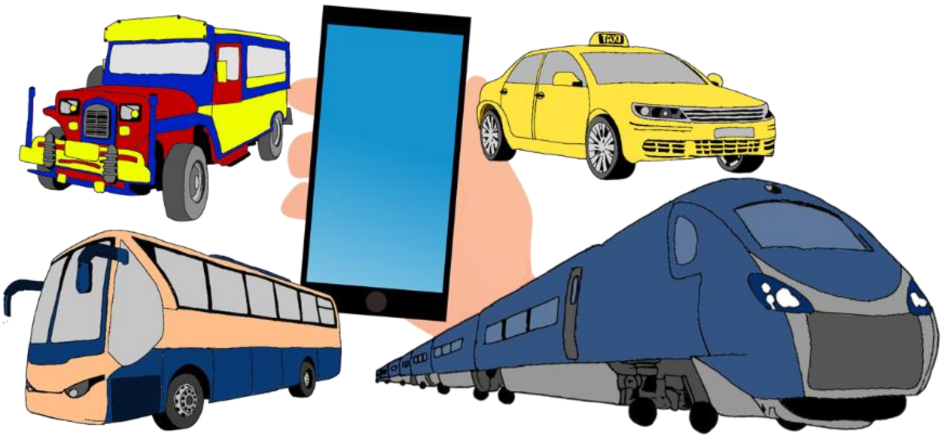


Figure 4.2. Explanatory image about the integration of different transport modes in a MaaS scheme

After this background information was provided, the participants were asked whether they would use a MaaS app and how a MaaS system would influence their mobility behavior. The answers contained the following options with the respective frequencies in parentheses:

- I would probably use this app and use public transport more often (61 %)
- I would probably use this app, but wouldn't increase the use of public transport (23 %)
- I would probably NOT use this app, because I don't find it useful (3 %)
- I would probably NOT use this app, because I don't have a smartphone/mobile internet (0 %)
- I would probably NOT use this app for other reasons (5 %)
- I'm not sure (7 %)

4.3.3. Model estimation and analysis

Utility theory and discrete choice analysis are frequently used in transport research to explain choices between two or more discrete alternatives (e.g., mode choice). For comprehensive presentations on this subject the reader is referred to Ben-Akiva and Lerman (1985), Train (2009), and de Dios Ortúzar and Willumsen (2011). In this study, we conduct a binary choice analysis in which exactly two discrete alternatives are available.

First, we model the overall willingness to use MaaS (Model 1). For this purpose, we consider two groups: those willing to use a MaaS system (84 %) and all others (16 %). Note that we therefore initially do not take note of potential changes in mobility behavior (i.e., using public transport more often). At this point, we also do not account for the respondents' underlying reasons not to use MaaS (e.g., because they do not find it useful).

In the second part of our analysis, we take a closer look at the respondents willing to use MaaS. We therefore draw on a subset of the sample consisting of the 84 % that responded accordingly (i.e., N=199). Here, we intend to model the potential MaaS-users' likelihood to use more public transport in a MaaS system (Model 2). We again consider two groups: those who would use public transport in a MaaS system more often (73 %) and those who would not (27 %).

We relate the respondents' willingness to use MaaS (Model 1) or the likelihood of using public transport more often (Model 2) to their individual mobility, socio-demographic, and household characteristics:

$$y_j^* = \beta x_j + \varepsilon_j, \tag{4.1}$$

where y^* is an unobserved latent variable, β a vector of estimated coefficients, x_j a vector of the values of the j-th observation, and ε_j the unobserved error term. The relation between the unobserved latent variable y^* and the observed binary variable y indicates whether the relative perceived utility of respondent j to use MaaS (Model 1) or more public transport in a MaaS system (Model 2) is positive:

$$y = \begin{cases} 1 \; if \, y^* > 0 \\ 0 \text{ otherwise} \end{cases} \tag{4.2}$$

In short, Model 1 relates a stated intention to use MaaS with individual, household, and mobility-related characteristics. The latent variable *y** measures the perceived utility that each user associates with using MaaS (following a written explanation about the MaaS concept and characteristics, a visualization, and a video presentation). This utility is not directly observable. What we observe is the stated intention to adopt MaaS, that we denote by the dichotomous variable *y*=1 if the perceived benefit of using MaaS (as opposed to not using) is positive. Similarly, Model 2 relates the stated intention of using more public transport in a MaaS-system with individual, household, and mobility-related characteristics of the respondents.

We use the software package NLOGIT 4.0 to perform the maximum likelihood estimation of both a standard probit model (equation (4.3) and a heteroscedastic probit model (equation (4.4). The latter accounts for possible heteroscedasticity – which is frequently encountered in micro-level data – and allows the error variance to depend on some of the independent variables in the regression model (Alvarez and Brehm, 1995). The key difference, therefore, is the inclusion of the variance model in the denominator of the latter equation.

$$ln\mathcal{L}(\beta|x_i, y_i) = \sum_{i=1}^{n}\Big(y_i ln\phi(x_i\beta) + (1-y_i)\ln\big(1-\phi(x_i\beta)\big)\Big) \tag{4.3}$$

$$ln\mathcal{L}(\beta,\gamma|x_i, y_i, z_i) = \sum_{i=1}^{n}\left(y_i ln\phi\left(\frac{x_i\beta}{exp(z_{i\gamma})}\right) + (1-y_i)ln\left(1-\phi\left(\frac{x_i\beta}{exp(z_{i\gamma})}\right)\right)\right) \tag{4.4}$$

For the selection of variables in the model, we follow the purposeful selection process which is a widely used approach to identify significant covariates and confounders (Bursac et al., 2008). For the univariate analysis, it recommends a p-value cut-off point of 0.25. For our models, we use a slightly higher value (0.28) to be able to include relevant variables for this study (e.g., the respondents' residence).

The McFadden Pseudo R^2 is frequently used as a goodness-of-fit metrics in logistic regression and reflects the degree of improvement over a base model. Here, we rely on the adjusted version to penalize for the number of predictors in the model. Note that this index can yield negative values, and that regarding its interpretation, it cannot be compared to the (adjusted) R^2 of linear models.

Finally, we validate the results of the models. We note that while a structured approach towards model validation is not frequently applied in the transport literature (Parady et al., 2021), the models' effectiveness should indeed be analyzed before the models can be used. Besides the common interpretation of the models' parameters (that provide initial insights about the accuracy of the models' specification), cross validation is used to detect overfitting. As no other similar data is available, we use the k-fold method to split the original data into k mutually exclusive data sets. Considering the small size of our sample, we define $k = 3$ to ensure there remains full representation of conditions in all data sets. Each data set is once defined as a hold out (validation data set), while the remaining data is used for the model estimation (training data set). We then regard the model evaluation scores to summarize and compare the skill of the model on new data. In addition to the percentage of correct predictions (actual 1s and 0s correctly predicted), we also report the negative predictive value (predicted 0s that were actual 0s) to account for the fact that our samples are rather skewed (e.g., recall that 84 % stated that they would likely adopt MaaS) and that a trivial model that always predict "1" would thus obtain a high correct prediction score. The interpretation of the negative predictive values, therefore, helps to further evaluate that the models can really discriminate between actual 1s and actual 0s (due to the explanatory variables included in them).

4.3.4. Research limitations

As we noticed during the pre-survey, a MaaS scheme in MM and especially the introduction of mobility packages[17] would be a novel and revolutionary scenario. While we have made every effort to describe the MaaS concept as aptly as possible – given the fact that MaaS is still a near to unknown phenomena in the Philippines – we cannot guarantee that the respondents fully understood the MaaS concept and what it could mean to them. Note that we therefore included the "I'm not sure" option in the survey.

The online data collection implies that we could not reach citizens without internet access (and smartphones). Instead, the online survey primarily reached internet-affine individuals ('digital natives') which might have skewed the results towards positive views for MaaS. However, under consideration of the current conception of MaaS which requires smartphone possession and internet coverage, the potential user target group for MaaS is de facto restricted (Schikofsky et al., 2020). Hence, while our sample is not representative of the MM population, it is a subset of a potential user segment for MaaS wherein digital natives and so-called choice-riders might be overrepresented. Choice-riders can and do afford motorized private vehicles and they therefore need to be addressed when promoting a paradigm shift – which corresponds to one of the research questions that we explored in this study.

[17] Note that nowadays in MM there do not even exist seasonal tickets of any kind (e.g., monthly passes, etc.).

There are also some biases that we cannot control for, which is why the results of this study should be considered as preliminary. First and foremost, this relates to the use of a small sample size, which typically leads to higher variability. Another potential issue relates to endogeneity. In discrete choice models, endogeneity arises when some explanatory variables are correlated with the error term. This is almost unavoidable in transport modeling and can occur due to omitted variables, measurement or specification errors, and/or self-selection (Guevara, 2015). In our study, one can expect that particularly the mode choice indicators (travel cost, travel time, reliability, comfort, safety, etc.) are prone to endogeneity (Guevara, 2015).

Since there is currently no operational MaaS scheme in MM, our modeling approach is based on a stated intention to use MaaS, which does not necessarily align with the respondents' actual behavior. This is due to, for example, hypothetical biases (e.g., respondents overreport "desirable" behaviors), changes in explanatory variables (e.g., unanticipated income shifts), and the imperfect correlation between intentions and actions (Sun and Morwitz, 2010). Also, even though the concept of mobility packages was explained, we did not explicitly ask respondents whether they in fact would subscribe to a MaaS-plan and how much they would be willing to pay.

Nevertheless, since we analyze a premature market (i.e., MaaS in a developing country), we argue that these limitations are not critical at this point and, instead, should be addressed in future research (as discussed in Section 4.6).

4.4. Study results

4.4.1. Model 1: Willingness to use MaaS (whole sample)

The first model includes eight independent variables: the respondents' residence (RESID), Number of modes (MODE), ride-hailing trips (TRIPS-RH), distance traveled (DISTAN), number of transfers (TRANSF), price and reliability factors (PRICE, RELIABILITY), and gender (SEX) (Table *4.6*).

For the heteroscedastic probit model, we include the respondents' gender and age in the variance model which are frequently detected with heteroscedasticity for many kinds of behavioral variables (Goldstein, 2014). Considering the log likelihood for the standard probit (-90.37) and the heteroscedastic probit model (-90.17), we can use the likelihood ratio test to validate whether the error variances are homoscedastic. The value of 0.4 (distributed chi-squared) with 2 degrees of freedom is clearly below the critical value of 9.21 (at p < .01). We can therefore not reject the null hypothesis and conclude that heteroscedasticity is likely not an issue in our data and that the standard probit model is sufficient.

Table 4.6. Estimated results of the standard probit model on the decision to use MaaS (Model 1)

Variable	Description	Coefficient	SE
(Constant)		.48069	.49185
RESID	Place of Residence	.34267	.30899
MODES	Number of modes	.07761	.05504
PRICE	Price (Mode choice)	.62325***	.22402
RELIABILITY	Reliability (Mode choice)	.81071**	.35258
TRIPS-RH	Ride-hailing trips	.39262**	.17911
TOTDIST	Distance traveled	-.20023*	.11784
TRANSFERS	Number of transfers	-.04058	.07882
SEX	Gender	-.47887**	.21663
Model Summary Statistics			
Number of observations:		238	
Number of model parameters:		9	
LL($\hat{\beta}$)		-90.36884	
LL(c)		-106.1539	
McFadden Adjusted Pseudo R-squared:		.0733374	

* 90 % Confidence Level; ** 95 % Confidence Level; *** 99 % Confidence Level

Model 1 gives insights about the potential MaaS users in MM considering mobility-related and socio-demographic characteristics. The variables PRICE and RELIABILITY are both significant and have a positive coefficient, which indicates that price-sensitive citizens are a potential target group. For them, MaaS would be an opportunity to plan trips, compare travel alternatives, and choose the best option. The significance of TRIPS-RH suggests that frequent ride-hailing users are willing to use MaaS. Ride-hailing services are typically used for short social and leisure trips (Rayle et al., 2016), for which MaaS could provide suitable and more sustainable travel alternatives. The negative coefficient of the SEX variable shows that females in our sample are more likely to adopt MaaS, which aligns with studies related to public and soft modes suggesting that males attach a higher psychosocial value to cars and drive more often (Vance and Peistrup, 2012).

The number of transport MODES used regularly has a slight positive impact (though not statistically significant), while TOTDIST traveled shows a negative correlation. Taken together, the model therefore provides some (weak) evidence that MaaS attracts citizens that already rely on multiple transport modes and that MaaS is seen as an opportunity to facilitate multimodal travel on short distances. Citizens living in MM (which corresponds to RESID=1), furthermore, show a greater interest to adopt MaaS compared to those living in the adjoining provinces. A possible explanation relates to the main trip purpose of respondents. Those living in the provinces typically travel to MM for work/business or school (94.3 %) suggesting that they use the same daily routes. MM residents show a higher variety in trip purposes including those related to social and leisure activities (11.6 %), which often implies that they travel to varying destinations and may be willing to use MaaS as a trip planner.

Interestingly, the willingness to use MaaS did not correlate to the respondents' age. We report strong interest in MaaS across all age groups – the lowest percentage of respondents that stated that would probably use MaaS was as high as 74 % for the age group 40-49 years old. The highest percentage (86 %) was recorded for respondents between 20 and 29 years of age. This contrasts with what has been observed in previous studies, for example in Germany and the UK, where the older segments showed a significantly lower interest in MaaS (Ho et al., 2020; Schikofsky et al., 2020). We further note that there was no correlation found with regards to households' vehicle ownership or income levels.

With regards to the cross validation, the estimated models of the training data set provide an average predictive accuracy of 83.82 % which is comparable to the predictive performance of Model 1 (83.61 %) and a model without predictors (83.61 %). Similar results are obtained for the validation data sets (83.18 %, on average). The negative predictive values show robust results for both the training (46,20 %, on average) and validation data sets (48,33 %, on average), which are roughly comparable to the results of Model 1 (50,00 %) and a significant improvement over a constant model (0,00 %). We conclude that the variables contribute to the predictive performance of Model 1 and that overfitting is not an issue.

4.4.2. Model 2: Likelihood of increasing the use of public transport (among MaaS adopters)

The independent variables included in the second model are the following: the respondent's residence (RESID), modal choice factors such as PRICE and RELIABILITY, the number of trips by public transport and taxi (TRIPS-PT, TRIPS-TX), the trip purposes PERSONAL and BUSINESS, gender (SEX), and the number of transport applications installed on the respondent's smartphone (APPS) (Table *4.7*).

Table 4.7. Estimated results of the standard probit model on the decision to use public transport more often in a MaaS-system (Model 2)

Variable	Description	Coefficient	SE
(Constant)		1.12008**	.45470
RESID	Place of Residence	-.95301**	.39062
PRICE	Price (Mode choice)	.37428*	.22129
RELIABILITY	Reliability (Mode choice)	-.57037**	.26736
TRIPS-PT	Public transport trips	-.03972	.08347
TRIPS-TX	Taxi trips	.30441	.31494
PERSONAL	Trip purpose “personal”	-1.00121**	.41405
BUSINESS	Trip purpose “business”	.32823	.36389
SEX	Gender	-.39427*	.21341
APPS	Number of transport apps	.35247**	.15282
Model Summary Statistics			
Number of observations:		199	
Number of model parameters:		10	
LL($\hat{\beta}$)		-92.81975	
LL(c)		-106.1539	
McFadden Adjusted Pseudo R-squared:		.040829	

* 90 % Confidence Level; ** 95 % Confidence Level; *** 99 % Confidence Level

Among the respondents that would adopt MaaS (84 % of the total sample), almost three forth stated that they would use public transport more often. The significance of PERSONAL implies that trip purpose is relevant, and its negative coefficient further indicates that additional public transport trips are expected to be made for motives other than personal trips. Based on the variable RESID, we further find strong evidence that citizens living in the adjoining provinces are willing to use more public transport. This could relate to the current lack of adequate access to public transport in the periphery and in the provinces (Abad et al., 2019). This suppressed/latent demand could be addressed by MaaS through the integration of shared and on-demand services (as a feeder to the mass transit hubs). Additionally, we find that price-sensitive citizens (PRICE) and females (SEX) are not only more willing to adopt MaaS (recall Model 1 above), but they also refer to the users who would use public transport more often. In contrast, users seeking for RELIABILITY would likely not increase the use of public transport. Another important finding refers to the number of transport apps (APPS) that the respondents have installed on their device. We find evidence that with increasing number of installed apps, the willingness to use more public transport increases. MaaS could therefore be a solution to consolidate the growing number of NMS and different service providers and reduce barriers to use public transport for ‘digital natives’ who prefer to plan, book, and pay services online.

The different model specifications in the cross validation show a roughly comparable predictive accuracy (78.36 %, on average) compared to Model 2 (77.39 %), and an improvement over a constant model without predictors (72.86 %). However, while we observe that the results for the validation data sets are rather unstable, we argue that they are reasonably close to the predictive performance of Model 2 (within 3–10 %). With regards to the negative predictive values, the average results for the training (68,94 %) and the validation data sets (65,65 %) are roughly comparable to Model 2 (64,52 %). If compared to the result of a model without predictors (0,00 %), it suggests that the variables contribute to the predictive performance of Model 2. We also conclude that overfitting is not an issue.

4.5. Policy implications

In our sample, half of the respondents traveled less than 15 km in MM on the previous day while the average travel time corresponded to 2.39 hours. This describes the current traffic situation in MM very accurately and stresses why citizens (who can afford it) rely on private cars and low-capacity for-hire services such as taxis and ride-hailing. Yet, we found evidence that both the willingness to use MaaS (84 %) and the willingness to increase public transport usage in a MaaS-system are high (61 % of the total respondents which corresponds to 73 % of the potential MaaS users). This indicates that MaaS has the potential to be an effective strategy to promote public (and non-motorized) transport modes and tackle GHG emissions and other car-related social costs (e.g., traffic congestion, accidents, and noise) through modal shifts.

Accordingly, the study results provide important implications for public policy and practice, and influence how MaaS can be implemented in the developing world.

The most important question, in this context, relates to who should plan and implement the MaaS scheme. Essentially, previous research suggests two scenarios: a public or a private pushed development (or a combination of both) (Smith et al., 2018).

Findings from ride-hailing show that the private sector usually follows economic rather than sustainability objectives and thus contributes to increases in traffic congestion and overall vehicle-miles traveled (VMT) (Tirachini, 2019). These findings have been confirmed in the developing world, particularly in the context of Southeast Asian megacities (Suatmadi et al., 2019; Yuana et al., 2019).

Under a private pushed MaaS development, therefore, the risk could be that the MaaS operator compels occasional public transport users towards the use of less sustainable (and more expensive) transport modes of the MaaS-mix (e.g., carsharing or ride-hailing).

Thus, we argue that transport agencies should anticipate and address the existing demand for multimodal transport. Ambrosino et al. (2016) highlight the crucial role of transport agencies with regards to the integration and coordination of different modes and operators, which is urgently needed in cities such as MM. Ideally, we therefore envision a scenario in which the public sector plans and governs the MaaS scheme under consideration of sustainability goals. The available levers (e.g., pricing and bundling techniques), hereby, should be used to promote and favor environmentally friendly transport modes.

Nevertheless, the question arises as to whether emerging cities in developing countries, such as MM, can implement a complex project of this kind. Existing research has pointed out that the institutional setup in MM is extremely slow and convoluted, which has hampered the implementation of previous sustainability transport projects (e.g., cycling networks, BRT, etc.) (Pojani, 2020). Experts additionally point to barriers related to technology (e.g., available ICT infrastructure, the need for standardized open data) and the external environment (e.g., highly fragmented operator landscapes, car-centric developments) that developing cities have to face (see Chapter 5).

A window of opportunity for MaaS implementation, however, could lay in the current COVID-19 crisis. It is believed that pandemic response measures, amongst others, propel digital transitions and a shift towards sustainable transport (Megahed and Ghoneim, 2020). Indeed, despite the overall decrease in travel demand, several transport policies in favor of MaaS have recently been introduced in MM (see Chapter 3). In Resolution No. 69 dated September 7, 2020, for example, the IATF-EID ordered the establishment of an interoperable automatic fare collection system and the promotion of cashless payments. Whereby the NTP and its IRR stipulate efficient data collection and an open database system for all governmental transport agencies.

For the successful implementation of MaaS in developing countries, it is important to notice that different user motivations and reasons to adopt MaaS compared to findings in developed countries have been identified (Table 4.8). For example, citizens in MM would not adopt MaaS for environmental reasons but rather for reliability and cost saving reasons. Accordingly, the MaaS providers should leverage users' practical concerns and economic motivations.

Table 4.8. User motivations and reasons to adopt MaaS

Findings based on trials and research in Developed Countries	New user perspectives for MaaS in Developing Countries (Metro Manila)
– Curiosity (Sochor et al., 2016) – Convenience/flexibility and (re)discovery of alternative modes (Karlsson et al., 2016) – Increased accessibility (Fioreze et al., 2019; Sochor et al., 2016) – Environmental awareness (Fioreze et al., 2019)	– Expectation of a more reliable service (e.g., through the integration of different services, travel information, and identification and comparison of travel alternatives) – Expectation of cost-savings – Mobility solution for all age groups – Consolidation of different services in a single app

Indeed, MaaS delivers much potential to make user travel more reliable. ICT integration would enable the provision of all relevant travel information (e.g., travel and arriving times, transfer points, and costs) and would always suggest suitable, multimodal travel alternatives. This could potentially also deliver an improved travel experience as users would have the chance to avoid overcrowded transport means, long waiting/loading times, and traffic jams.

With regards to the potential of cost savings, it is argued that MaaS could significantly reduce costs as a substitute to private cars (i.e., by eliminating the sunk cost of vehicle ownership), even though it is not clear whether car owners would really dump their cars for MaaS. Through the introduction of mobility packages, also households without cars could potentially undercut their current mobility costs. This depends very much on the design of the mobility packages and potential subsidies of services, which should therefore be the subject of future studies.

4.6. Conclusion and future research

MaaS is still a developing concept and academic research on MaaS is in its early stages. From both practical and theoretical standpoints, findings regarding developing countries are particularly limited. We addressed this knowledge gap with an analysis on the demand side in MM, Philippines.

Two binary probit models have been estimated that help transport authorities and MaaS stakeholders (operators, aggregators, etc.) identify (i) who the potential MaaS users are, and (ii) whether they would be willing to use more public transport in a MaaS scheme. The models were validated using a cross-validation approach.

In our study, the vast majority (84 %) stated that they would probably use a MaaS-app. Even though this percentage appears surprisingly high, the fact that more than 90 % of respondents already have at least one transport app installed on their device relativizes this number. Many citizens in MM are familiar with transport apps, especially ride-hailing (e.g., *Grab* and *Angkas*), and are aware how to plan, book, and pay trips online using smartphones. We need to emphasize that in order to reduce complexity, however, we only asked users if they would generally use MaaS – be it a 'pay-as-you-go' or a subscription-based alternative.

While environmental awareness does not appear to be a relevant aspect in the adoption process, we conclude that MaaS could provide added value to users by increasing reliability, reducing costs, and facilitating multimodal trips. In addition, we found evidence that MaaS has the potential to shape more sustainable transport systems in developing countries as it could help to make public transport more attractive and induce a modal shift. MaaS could furthermore promote more inclusive mobility by addressing latent demand in the periphery and in adjoining provinces that often lack adequate access to public transport.

The results of this study provide preliminary insights for transport planners and policymakers on how MaaS can promote sustainable transport and are replicable in the context of comparable developing cities. We conclude that MaaS can be a potential strategy to tackle both mobility and environmental issues. In face of the diverse transport problems that developing cities such as MM are currently facing, we highlight the utmost importance of these preliminary findings.

In order to build a future with MaaS in developing countries where it can deliver on its full promises, we stress that comprehensive research is still very much needed. While our research gives initial insights about MaaS in developing countries, it is also meant to be a door opener for additional research.

More attention on MaaS in the media landscape and additional pilots and trials in the region would contribute to the dissemination of the MaaS concept, which would facilitate a more profound investigation of MaaS adoption in developing countries. A larger and more representative sample is needed to obtain fully conclusive results. We recommend stated choice/preference experiments (as well as other suitable methods, see Table *4.2*) to investigate the demand and the willingness to pay (WTP) for different mobility packages. As is crucial for quality forecasting, future research should also address the endogeneity problem and (if necessary) correct this possible bias – for example, using instrumental variable techniques.

As our sample is skewed towards rather young (20-39 years) and tech-savvy adults, the particular needs of children and teenagers (Casadó et al., 2020), elderly citizens (Mulley et al., 2020), and the lower-income groups merit additional attention. Considering that in social terms the current transport systems in many developing cities are disproportionately affecting lower income groups (Hickman et al., 2017), one of the most important research questions relates to how these groups (that often do not have access to the internet) can benefit from MaaS.

Other promising lines of future research relate to governance, the supply side, and how MaaS can be implemented in developing countries. In this context, scholars should identify suitable governance approaches, optimal BMs, and necessary adaptations of the MaaS concept.

Finally, large-scale simulation studies that quantify MaaS-related benefits and costs (under different scenarios) could deliver additional knowledge to promote MaaS schemes in developing countries.

Chapter 5

5. Transport authorities and innovation: Understanding barriers for MaaS implementation in the global South

5.1. Introduction

Triggered by digital technologies and by societal changes, NMS such as ride-hailing, carpooling, and car-, (e-)bike-, and (e-)scooter-sharing have recently disrupted the way people move in and between cities. MaaS builds on this development and combines NMS with conventional modes of transport on a single platform accessible on demand (Jittrapirom et al., 2017). MaaS enables seamless, multimodal journeys and it is often acknowledged as an alternative to the private car. Scholars describe MaaS as an innovation (Surakka et al., 2018) and highlight its potential to promote sustainable mobility (Sochor et al., 2016). Indeed, first trials and MaaS schemes – e.g., *UbiGo* in Sweden (Sochor et al., 2016) and *Whim* in Finland (Ramboll, 2019) – as well as simulation studies (Becker et al., 2020) report promising results including the observation of modal shifts and expect reductions in transport-related energy consumption. However, these findings have primarily been derived in the context of the global North, where scientific publications (for a review, see Utriainen and Pöllänen, 2018) and conferences (such as the ICOMAAS series), government funding (e.g., within the EU Horizon 2020 funding program), and public-private partnerships (e.g., the MaaS Alliance) provide an ideal breeding ground for MaaS. In the global South, in contrast, MaaS is virtually a blank canvas. The authors conducted preliminary research on this topic using MM as a case study. They describe the potential role of MaaS in the post-pandemic future (see Chapter 3) and highlight the existing demand for MaaS, which leverages strong multimodal travel behavior, the rapid uptake of transport apps, and users' expectation of a cheaper and more reliable service (see Chapter 4). Similarly, Ye et al. (2020) found strong willingness to adopt MaaS in a Chinese town in the suburbs of Shanghai. Based on experiences from MaaS trials in Taiwan, Chang et al. (2019) argue that more sustainable travel choices can be promoted through the integration of on-demand services. In line with this, Pickford and Chung (2019) propose an incremental approach towards MaaS ("MaaS Lite") in Hong Kong in which on-demand services would contribute to better first/last mile connectivity. Khaimook et al.

(2019) investigated MaaS' potential to improve road safety. Results from their case study in Phuket, Thailand, suggests that MaaS indeed can encourage people to make safer travel choices. Singh (2020) describes a MaaS scheme in Kochi, India and shows that the inclusion of informal transport modes and the use of smart cards present some modifications of the known model from Europe.

In this research, we intend to contribute to the limited knowledge on MaaS in developing countries. We propose a public-pushed development towards MaaS and aim to shed light on potential implementation barriers that transport authorities might face on this road.

5.2. The role of transport authorities

A growing part of the MaaS literature is focusing on governance issues and the role of transport authorities. Case studies in Finland found that public sector engagement can be a catalyst for MaaS development (Mukhtar-Landgren and Smith, 2019), but also that more supportive roles could enable an even quicker uptake (Audouin and Finger, 2018). Meurs et al. (2020), in the context of a MaaS pilot project in Heyendaal, the Netherlands confirm that a supportive role of public authorities is vital for successful MaaS initiatives. Fenton et al. (2020) argue that this does not only relate to support on local level, but rather that a multi-level governance is required. In this context, different governance approaches have been identified (Hirschhorn et al., 2019), which involve a set of hard (e.g., legislative reforms, operational contracts) and soft (e.g., public strategies, R&D programs) policy instruments (Mukhtar-Landgren and Smith, 2019). Jittrapirom et al. (2018) highlight that these policies should be implemented in a dynamic, adaptable manner to increase robustness in uncertain future situations. Pangbourne et al. (2020) urge that public intervention is necessary for efficiency and transport equity reasons. Some experts even foresee a more proactive role of the public sector at operational level and argue that they are the most appropriate player to lead, plan, and/or operate MaaS schemes (Polydoropoulou et al., 2020). While little is known about the (potential) role of transport authorities for the implementation of MaaS in the global South, we argue that they should take up an anticipating role for twofold reason. First, the case of ride-hailing underlines that in a private-lead scenario, NMS would rather not contribute to a sustainable development and instead increase negative transport externalities by poaching patronage from public transport. Second, public transport systems in the global South – where informal transport services (e.g., minibuses, motorcycle taxis) are the predominant travel mode – are often rather rudimentary and lacking a holistic and integrated approach of planning. To address both environmental and transport-related problems, reforms of public transport regimes are therefore urgently needed. In this context, MaaS could be a data-driven approach to support much needed transport integration, route rationalization, transport planning and analysis, and so forth. Hence, we envision a scenario in which the public sector plans and governs the MaaS scheme, under consideration of sustainability goals, and using the available levers (i.e., pricing, subsidies, bundling techniques, reward points, etc.) to promote and favor green mobility behavior. This would translate either into a public-controlled or a public-private development (Smith et al., 2018). In both scenarios, transport authorities need to enlarge their scope and mission: taking up the role of the MaaS integrator in the public-private, and additionally filling the role of the MaaS operator in the public-controlled scenario.

5.3. Methods and data

In order to identify implementation barriers for MaaS, we conduct a literature review at the intersection of different fields of research, that is, MaaS in developed countries, transport in developing countries, and public sector innovation. Among the identified implementation barriers, we extract those that are relevant in the context of transport authorities and in their efforts to establish MaaS. Next, we apply the technology-organization-environment (TOE) framework to categorize the barriers (Table 5.1). TOE is a widely used framework that describes the entire process of (technical) innovations and how the three aspects' context influences innovation adoption and implementation (Baker, 2012). To determine to what extent the identified implementation barriers apply to implementing MaaS in the global South and whether there are additional implementation barriers specific to the global South context, we conduct an online expert survey consisting of two iterations. The experts (N=44) are selected based on the literature review, an internet search, and from the professional networks of the authors. They either (i) directly work on MaaS in global South context, (ii) work on MaaS and are familiar (e.g., through previous work) with transport and mobility in the global South, or (iii) work in the transport sector in the global South and are familiar with the MaaS concept. In the first iteration, the experts are asked to assess the relevance of the implementation barriers based on a scale from 1 (not relevant at all) to 5 (highly relevant) and describe any other implementation barriers that they expect. The second survey is structured similarly, however, this time, the respondents are asked to assess the newly suggested implementation barriers from the previous round. The descriptive statistics of the data allow us to compare the assessed implementation barriers and rank them based on their significance for developing cities. The results are then discussed against a backdrop of relevant studies in the literature. Finally, we derive policy implications and develop a model of MaaS implementation for transport authorities in the global South.

The survey has been answered by 29 experts in the first round and 21 in the second. This corresponds to a response rate of 65.9 % and 47.7 %, respectively. The profile of the expert panel is shown in Figure *5.1*. The sample comprises a cross section of different areas and backgrounds, whereas 'Academic/Research' represent the largest sector. Regarding regional expertise, there is a strong representation of Asia/Pacific which is the largest region (by population and land area) of the global South and where many (if not most) of the MaaS projects are underway. The experts identified themselves as very familiar with the MaaS concept and with transport and mobility in developing context (Table 5.1 & Table 5.2).

Figure 5.1 (a + b). Profile of the expert panel for (a) survey round 1 (N=29) and (b) survey round 2 (N=21)

5.4. Results and discussion

5.4.1. Expert survey round 1

Table 5.1 shows the results of the first round of the expert survey. A total of 34 implementation barriers have been assessed, whereby the average value corresponds to 3.60 with a standard deviation (SD) of 1.32.

Since MaaS is a data-driven approach to provide multimodal transport, various challenges arise in the technology context. The experts identified data related issues (4.41) and the difficulty to integrate and plan different transport modes and coordinating intermodal trips (4.38) as the most critical implementation barrier. Although transport authorities in the global North would probably have to face similar challenges, these implementation barriers are likely more pronounced in the developing context, given the lack of physical infrastructure (3.97) and the unavailability of key technologies (3.97). In practical terms, this means that if, for example, intelligent transport system infrastructure and essential ICT tools (such as RFID, GPS) are not available, this would impede MaaS implementation significantly.

The organization context involves challenges directly related to transport authorities. The expert panel particularly highlights the transport authorities' lack of experience and uncertainties regarding roles and responsibilities in the MaaS ecosystem (4.17) as well as transport authorities' entrenched structures, slow decision processes, and their lack of innovative strategies and integrated planning approaches (4.14). Transport authorities in the global South indeed seem to be less prepared for MaaS than their likes in developed countries, such as the German *Verkehrsverbünde* that have been planning and organizing integrated public transport services for decades. Furthermore, institutional setups of transport authorities in developing countries are often described as extremely slow and convoluted (Pojani, 2020), which in the past has delayed or even prevented the implementation of transport innovation projects. The lack of financial resources and funding (3.97) as well as complex and non-competitive public procurement practices (3.97) are additionally expected to hamper the development of Maas.

Considering that MaaS involves multiple stakeholders, it is not surprising that transport authorities are expected to face a large variety of implementation barriers in the environment context. According to the experts, barriers on the supply side outweigh those on the demand side. The most critical implementation barriers relate to the highly fragmented and individualized operator landscape (4.14) and the low level of operational transport modes and integrated mobility services (4.10). Indeed, a large number of self-account drivers of informal means of transport and the lack of regard for a holistic approach in urban transport planning are characteristic for the global South (Ferro et al., 2013). This impedes both the physical integration of transport services and the required cooperation with transport service providers (3.76). Another implementation barrier relates to the lack of private sector engagement and opposition from transport groups and associations (3.31) which in the past has hampered the implementation of transport reforms (Ferro et al., 2013). Implementation barriers that concern potential users are expected to have a somewhat low relevance. The lowest ranked implementation barriers relate to low technology adoption, poor digitalization, and low smartphone penetration in the population (2.59) as well as concerns regarding privacy and security of user data and low trust in digital/monetary transactions (2.48). Even though there seems to be some dissensus among the experts, they rather do not expect that MaaS implementation depends on the size and densification of the city (2.97; SD of 1.50) and that MaaS is only attractive for specific population segments (3.07; SD of 1.29). The latter represents a significant difference compared to findings in developed context highlighting that MaaS particularly attracts younger individuals (e.g., Caiati et al., 2020; Schikofsky et al., 2020). First studies in the global South, nevertheless, indeed report a different picture and found high interest in MaaS across different age groups (see Chapter 4; Ye et al., 2020). The most relevant implementation barrier on the demand side (yet with a score below of the average) has been identified as strong reliance on private cars (3.52). Even though MaaS is often praised as an alternative to the private car, to the authors' knowledge, there has not been any evidence in the scientific literature for this assumption so far. In contrast, existing studies on MaaS adoption often report that avid car users are likely not willing to change their travel habits (e.g., Caiati et al., 2020). In this context, it is important to notice that while in most industrialized countries car-ownership is stagnating at a high level or even decreasing, high motorization growth rates despite (still) low-levels of car-ownership are observed in many global South countries (Kutzbach, 2009). Typically, wherever rising per capita income is observed, more people can afford and do purchase private cars. Finally, legal concerns and the necessity of legislation change (3.69) has received a lower value than could be expected. Existing literature describe various legal conflicts, for example, related to government regulated pricing and ticket selling (Smith et al., 2019), commuting related taxation policies (Hesselgren et al., 2020), public procurement processes and franchising of public transport services (Wilson and Mason, 2020), and so forth. In global South context, these could be of less relevance due to the less formal and less evolved structures of public transport which could facilitate MaaS planning and operation (at least from a legal perspective).

Table 5.1. Assessment of implementation barriers for MaaS (expert survey round 1, N=29)

	AVE	SD	Score				
			5	4	3	2	1
MaaS expertise	4.38	1.16	19	6	2	0	2
Expertise on transport and mobility in developing context	4.34	0.90	16	9	2	2	0
Technology Barriers							
Data related issues (Standardization and aggregation of data, lack of open data, or unwillingness to share data)	4.41	1.02	20	3	5	0	1
Difficulty of integrating and planning different transport modes and coordinating intermodal trips	4.38	0.94	16	11	0	1	1
Lack of physical infrastructure (e.g., bike-sharing systems, charging stations for electric vehicles) to support MaaS	3.97	1.12	13	6	6	4	0
Difficulties related to technical integration / Unavailability of key technologies (including smart ticketing systems, ICT infrastructure, API's)	3.97	1.32	16	2	7	2	2
Perceived/expected benefits of MaaS (maturity of the concept)	3.83	1.14	10	10	3	6	0
Conflicts of branding (MaaS app vs. brands of service providers)	3.31	1.28	6	8	7	5	3
Platform related security issues (e.g., external attacks) and technology failure	3.28	1.16	5	8	7	8	1
Smartphone- and internet-related difficulties (battery life, mobile network access)	3.10	1.35	5	7	8	4	5
Organization Barriers							
Lack of experience / Uncertainties regarding roles and responsibilities across the actors in a new, emerging ecosystem	4.17	0.93	13	10	4	2	0
Transport authorities' entrenched structures, slow decision processes, and their lack of innovative strategies and integrated planning approaches	4.14	1.03	13	10	4	1	1
Lack of top management support	4.00	0.96	10	12	4	3	0
Lack of financial resources and funding	3.97	0.98	10	11	5	3	0
Complex, non-transparent, and/or non-competitive public procurement practices	3.97	1.12	12	9	3	5	0
Degree of centralization of the transport authority (and subordinated agencies)	3.90	1.11	11	8	7	2	1
High economic risks, huge marketing costs, and a long time to return on investment	3.45	1.02	5	9	9	6	0
Lack of ICT expertise	3.41	1.21	6	9	7	5	2
Environment Barriers							
Highly fragmented and individualized operator landscape	4.14	1.06	13	11	2	2	1
Low level of operational transport modes / integrated mobility services	4.10	0.94	12	10	5	2	0
Challenge to coordinate and reorganize different businesses/services and identify a viable/scalable business model	4.00	0.80	8	14	6	1	0
Stakeholders are unwilling to cooperate / refuse broker model	3.76	1.24	10	9	5	3	2
Legal concerns and conflicts / Process of legislation change takes too long	3.69	1.04	7	11	6	5	0

Lack of successful adoptions (serving as blueprints and inducing bandwagon pressure)	3.66	1.04	6	12	7	3	1
Challenge to design suitable mobility packages and offerings	3.52	1,27	7	10	6	3	3
Strong reliance on private cars	3.52	1.38	8	10	4	3	4
Lack of public sector engagement / political opposition	3.45	1.15	4	14	4	5	2
Necessity of a "window of (political) opportunity" / dependence on election cycles	3.41	1.15	5	10	8	4	2
Lack of private sector engagement / Opposition from transport groups and associations	3.31	1.00	3	10	10	5	1
Entry barriers for new startups or competitors to join potential MaaS platforms	3.18	1.13	5	5	8	11	0
Users refuse mobility plans (i.e., subscribing and paying in advance)	3.17	1.28	5	8	6	7	3
Users do not perceive added value / are unfamiliar with new transport modes and the MaaS concept / not willing to change travel habits	3.17	1.49	7	8	2	7	5
MaaS is only attractive for specific population segments (i.e., young individuals)	3.07	1.28	4	9	4	9	3
MaaS implementation depends on the size and densification of the city	2.97	1.50	7	4	5	7	6
Low technology adoption, poor digitalization, and low smartphone penetration in the population	2.59	1.05	1	5	8	11	4
Concerns regarding privacy and security of user data / low trust in digital transactions	2.48	1.33	2	6	5	7	9

5.4.2. Expert survey round 2

In the second round, 13 newly identified implementation barriers have been assessed (Table 5.2). The average value corresponds to 3.64 with a SD of 1.23. Note that the second survey has been sent to the same expert panel but was not answered by the exact same sample (although the expert profile for both rounds is similar) and that there was a lower response rate.

Table 5.2. Assessment of implementation barriers for MaaS (expert survey round 2, N=21)

	AVE	SD	Score				
			5	4	3	2	1
MaaS expertise	4.48	0.81	13	6	1	1	0
Expertise on transport and mobility in developing context	4.67	0.48	14	7	0	0	0
Technology Barriers							
Difficulty of integrating (informal) paratransit services	4.38	1.02	14	3	2	2	0
Need for adjustments: There is no standard model for implementation	3.48	1.29	5	7	4	3	2

Lack of payment enablers/high costs of transition to electronic payments	3.48	1.33	6	6	2	6	1
Organization Barriers							
Necessity of political support in data-sharing and integrated systems to support MaaS	4.05	0.97	8	8	3	2	0
Lack of institutional capacity in governments to manage information	4.05	1.16	10	5	4	1	1
Lack of (or unsuccessful) education and communication initiatives about MaaS	3.19	1.29	4	5	5	5	2
Environment Barriers							
Deep bias for private automobile use and ownership among the elite	4.24	0.77	8	11	1	1	0
Developing and maintaining trust among involved stakeholders	3.86	0.79	3	14	2	2	0
Lack of existing platform providers to open their business model / Lack of interest from scaled-up MaaS players in low-margin markets of the developing world	3.52	1.44	6	8	1	3	3
Other transport projects should have priority (e.g., active transport infrastructure)	3.48	1.29	4	9	4	1	3
Lack of confidence in traveling with mass transit and shared services (due to COVID)	3.43	1.33	6	5	3	6	1
Cultural and attitudinal issues about usage of alternative modes	3.29	1.23	4	6	4	6	1
Major ride-hailing apps have created a reluctance towards public transport apps	2.90	1.18	3	3	5	9	1

The difficulty of integrating and planning different transport modes has been discussed above. For cities in the global South, this particularly relates to the integration of informal transport services (4.38), which was the highest ranked implementation barrier in this round. The need for adjustments (3.48) – considering that there is no standard model for implementation – arguably also applies to MaaS projects in developed context. However, for transport authorities in the global South, this could be more challenging due to their lack of experience and capacities (as discussed in the organization context). The lack of payment enablers and high costs of transition to electronic payments (3.48), indeed, appears to be very relevant for developing cities. Except for some mass transit solutions (e.g., MRT, BRT) that deploy smart card systems, cash payments are usually the common practice for public transport services in the developing world. While smart card solutions require the equipment of costly infrastructure in transit terminals (and vehicles), digital payments require the additional cooperation with payment enablers.

The implementation barriers in the organization context support the expectation that managing data-driven systems such as MaaS is a great challenge. While transport authorities' support in data-sharing and integrated systems is needed (4.05), it is questionable whether they have the institutional capacity to manage the aggregated information (4.05). Finally, the lack of (or unsuccessful) education and communication initiatives to create awareness for MaaS does not seem to be a very relevant implementation barrier (3.19).

Although a strong reliance on private cars by the population has been assessed rather uncritical for MaaS implementation, a deep bias for private automobile use and ownership among the elite (4.24) – a minority group with disproportionately high impact on policy discussions – could hamper the MaaS implementation. While the necessity of cooperation has been highlighted in the previous round, developing and maintaining trust among the involved stakeholders (3.86) was assessed relevant in this round. This seems plausible, considering that due to high costs and the long time to return on investment, MaaS initiatives should always be designed for the long term. The lack of or the lack of interest of existing platform providers (3.52) would only be of relevance in a public-private development. If this would lead to the absence of competition, this could impair the MaaS system's performance and drive up costs.

5.5. Policy implications

The results of the analysis highlight the interrelation of the three contexts (Figure 5.2) and show that implementing MaaS schemes in the global South is a difficult proposition that requires a fundamental amount of time, resources, and know-how. The technological context thereby represents the crux for MaaS development: the most critical implementation barriers relate to data related issues, the difficulty of transport integration and planning, and the lack of supporting infrastructure. The organization context shows that external funding and expertise as well as internal reforms and the re-organization of transport authorities are needed in order to adequately manage data and information and to plan multimodal transport services. While the environment context involves manifold implementation barriers, it appears that many of them are less critical for MaaS implementation (e.g., those related to the legal framework and potential users). Here, despite low car ownership, the biggest challenge appears to be the car-centric development led by minority elites. This bias – which is affecting policy directions, urban planning practices, and infrastructure investments – needs to be resolved. Also, policies addressing the informal setup of public transport regimes and to incentivize cooperation among transport operators are urgently needed.

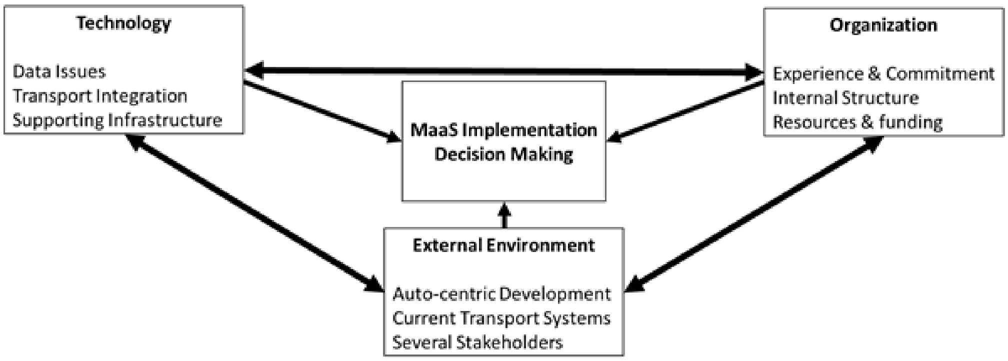


Figure 5.2. Model of MaaS implementation for transport authorities in the global South

5.6. Conclusion

The present study contributes to the incipient literature on MaaS governance issues. We addressed this topic in the context of the global South which has been widely overlooked so far. Through the identification and discussion of the specific implementation barriers, we provide additional insights on the capabilities of developing cities to establish MaaS and other transport innovations. Addressing the lack of public sector perspective in transport innovation studies (i.e., how to foster technological change), we apply the TOE framework to the context of transport authorities and MaaS. Considering the large study dimension and the heterogeneity of the regions of the global South, we need to mention that our sample size is relatively small. Note, however, that following the theoretical saturation criterion, we stopped the data collection at the point where we obtained no more new information/insights (i.e., additional barriers). Note, also, that it was difficult to identify relevant MaaS schemes and experts working in this field due to the lack of a generally accepted definition of MaaS (Jittrapirom et al., 2017) and the fact that MaaS is just starting to gain traction in the global South. The data from this study can be used for a more profound analysis and discussion. For example – as the authors intend in future work – to model implementation barriers using interpretive structural modeling (ISM) or similar techniques to understand the relationship between the implementation barrier, develop simplified graphical representations of complex systems, and to analyze its implications for the implementation of MaaS in the global South.

Chapter 6

6. MaaS for the masses: potential transit accessibility gains and required policies under Mobility as a Service

6.1. Introduction

Due to its heavy fossil fuel consumption and the reliance on carbon-intensive infrastructure, the transport sector is one of the largest emitters and fastest-growing source of global GHG emissions (Lamb et al., 2021). Hence, decarbonizing the transport sector is of utmost importance in order to mitigate anthropogenic climate change and to meet the 1.5 degrees Celsius target of the Paris Agreement (Creutzig et al., 2015).

This instantly relates to the global North, where the private car has become the most dominant transport mode after decades of car-centric developments. However, while it is claimed that many developed countries have already surpassed 'peak car' (Metz, 2013), the fastest transport-related GHG emissions growth is observed in the global South (i.e., in Eastern Asia, Southern Asia, South-East Asia, and Africa) (Lamb et al., 2021). Global megatrends such as population growth, urbanization, and high motorization rates are likely to propel such growth in the future. As many countries of the global South are already facing the environmental consequences of global warming and climate change (i.e., sea-level rise, extreme weather events, droughts, wildfires, and so forth), countermeasures and immediate action are indeed urgently needed (Schleussner et al., 2018).

Behavioral shifts, thereby, have the potential to be more rapid and widespread than any technological advance. In other words, individuals' decisions to not own a private car and instead rely on more sustainable transport modes (e.g., walking, cycling, and public transport), for instance, could collectively have a greater impact on decarbonizing the transport sector than any advances made by cleaner fuels or alternative powertrains (Wright and Fulton, 2005; Wynes and Nicholas, 2017).

A prominent reason that inhibits the use of public transport in developing cities is the lack of access to transport infrastructure and services, however. This does not only impair sustainable mobility behavior, but also exacerbates social exclusion and inequalities (Preston and Rajé, 2007). Transport-related social exclusion could result in lower involvement in social activities, lower opportunities for social advancement, involuntary unemployment, and many other social and economic disadvantages (Lucas, 2005).

Under the premise to make cities more inclusive and sustainable (Sustainable Development Goal - SDG 11), the United Nations (UN) thus have set the target (SDG 11.2) to "[…] provide access to safe, affordable, accessible and sustainable transport systems for all […]" by 2030. In this regard, an indicator (SDG 11.2.1) to quantify the "proportion of population that has convenient access to public transport […]" has been proposed (UN, n.d.). The operationalization of this indicator has been defined as the "percentage of people within 0.5km of public transit running at least every 20 minutes" (Indicator Report, n.d.). While some of the most developed cities in the world reach scores close to 100 % (mainly transit oriented cities in Europe, e.g., Barcelona/Spain: 99.68 %; Genova/Italy: 99.5 %; Brighton/UK: 99.31 %), less developed cities make up the bottom of this ranking (e.g., Bur Sudan/Sudan: 4.49 %; Lubumbashi/Congo: 4.56 %; Irbid/Jordan: 4.64 %) (UN, n.d.).

In this research, we discuss an opportunity – that we consider to be low-cost and high-impact – for developing cities to address this accessibility problem: the shift towards MaaS. MaaS is a recent phenomenon and frequently praised as an alternative to the private car. It aims to provide seamless, intermodal travel options by integrating public and private transport modes on a single platform accessible on demand (see Arias-Molinares and García-Palomares, 2020b and Jittrapirom et al., 2017 for comprehensive presentations on this topic). First studies and field trials, indeed, find that MaaS – if implemented in combination with suitable policies and governance approaches (Pangbourne et al., 2020) – could be a promising pathway towards more sustainable mobility futures in both developed (e.g., Becker et al., 2020; Sochor et al., 2016) and developing context (e.g., see Chapter 4; Singh, 2020). While MaaS would actually not increase the value of the SDG 11.2.1 indicator (as per UN definition)[18], the integration of feeder modes, however, could indeed improve the access to public transit. In this research, we specifically focus on the possible integration of informal transport[19] and micro-mobility.

Using a novel approach that leverages open data sources and that is easily replicable to different contexts, we use MM as a case study to calculate the potential transit accessibility gains under MaaS.

[18] In principal, this can be achieved through making additional transit stops and services available and/or through the provision of housing in proximity to the transit infrastructure. The latter in particular requires a fundamental amount of time and financial resources.
[19] We support the view by Ferro et al. (2013) that public transport transformation projects do not require the formalization or substitution of informal transport services, and that they rather can be integrated with, and complement, (formal) public transport services.

MM is a characteristic megacity in the global South in which enormous social and transport-related inequalities are observed. While essentially transport infrastructure investments and/or public transport reforms (e.g., Boquet, 2013; Regidor et al., 2017) have been discussed in the literature to address the transport woes in this region, our previous study highlights the existing demand and the citizens' willingness (84 %) to adopt MaaS (see Chapter 4).

The contribution of this chapter to the scientific literature is twofold. First, we contribute to the incipient literature on micro-mobility and MaaS, and provide empirical evidence and quantifications of integrated transport's potential benefits, all in developing context. Second, we contribute with a comprehensive and evidence-based policy discussion on how developing cities and transport authorities can foster a sustainable development under MaaS and build more equitable transport systems for the future.

The remainder of this chapter is structured as follows. Section 2 provides the background for this study. Section 3 details our data and methods. The study results are presented in Section 4 and policy recommendations in Section 5. Finally, concluding remarks and future research paths are outlined in Section 6.

6.2. Towards MaaS: the emerging mobility ecosystem

Urban transport is currently experiencing a major transition which harbors considerable potential to foster sustainable mobility (Creutzig et al., 2019). This transition is being triggered by technological trends (e.g., digitalization and electrification) as well as by societal and market changes (e.g., decarbonization and the rise of digital platforms). Mainly driven by innovative start-up companies (*Uber*, *Lyft*, *Grab*, *Tier Mobility*, etc.) and financed by venture capitalists, this has led to the development of new concepts of mobility – also labeled as NMS (Cassetta et al., 2017). These NMS have changed the way people travel in and between cities. In Chapter 2, we show that NMS typically spring from developed lead markets (e.g., San Francisco Bay Area) and from there diffuse globally including to the developing world, through expansion or imitation.

Most NMS are built on the principle of sharing either passenger rides or vehicles. The idea of sharing assets and resources of any kind is linked to a larger concept, the sharing economy. It typically promises several advantages such as cost-savings, increased efficiency, and avoidance of ownership liabilities (Parente et al., 2018). Sharing passenger rides – and in particular ride-hailing – has experienced tremendous success globally, due to the respective start-ups' aggressive expansion strategies into new markets, and leveraging on excess capacity (Goletz and Bahamonde-Birke, 2021). However, despite its advantages (improved comfort and safety, reduction of parking requirements, etc.), these services are also linked to negative externalities. For instance, due to low access/usage barriers and rebound effects, it is argued that they increase overall VMT and thus contribute to traffic congestion and air pollution, among other negative externalities typically associated with cars (Tirachini, 2019).

Furthermore, the concept of sharing vehicles has affected urban mobility in cities worldwide, especially since becoming available in “free-floating” (or dockless) fleets and accessible through smartphones. For the purpose of this research, the authors focus in the following particularly on lightweight vehicles that are also referred to as micro-mobility (e.g., bicycles and electric scooters). While the economic and environmental benefits of cycling as well as its contribution to physical health and well-being are well documented in the literature (see Oja et al., 2011 for a review), bicycle sharing (hereafter: bike-sharing) additionally eliminates some of the downsides of private bicycles. Consider the risk of theft, maintenance costs, and, in many cases, the unavailability to bring one’s bicycle on public transport. In times of disruptions (e.g., pandemics or strikes), bike-sharing has also proven to be more flexible and resilient compared to other transport modes (Teixeira and Lopes, 2020). As a first/last mile solution, bike-sharing has been found to have a positive impact on public transport use (Radzimski and Dzięcielski, 2021). Moreover, the substitution of private car trips implicates enormous potential for energy savings and GHG emission reduction (Zhang and Mi, 2018). Hence, bike-sharing is widely acknowledged as an efficient strategy for policymakers to decongest cities, improve citizens’ mobility, and to promote more sustainable urban futures.

The impact of electric scooter sharing (hereafter: e-scooter sharing) on urban development and overall sustainability, on the other hand, is more controversial. As electric powered vehicles, its contribution to cutting GHG emissions depends very much on which modes of transport e-scooter trips would replace (Hollingsworth et al., 2019). There is some evidence, however, that mostly active transport (in particular, walking) would be substituted (Laa and Leth, 2020; Sanders et al., 2020). From an environmental and societal perspective, this would rather be an undesirable outcome. Critics regarding public space interventions, safety concerns, and the tendency of traffic violations add to the existing debates (Tuncer et al., 2020; Sanders et al., 2020). Notwithstanding, similar to bike-sharing, e-scooter sharing has the potential to increase overall accessibility and connectivity of the transit network (Cao et al., 2021; Smith and Schwieterman, 2018). Many scholars therefore call for public sector interventions and regulation to elevate benefits and foster a sustainable development of e-scooter sharing (Laa and Leth, 2020; Cao et al., 2021).

The reciprocal effects of the different micro-mobility solutions have been the subject of recent studies. Unsurprisingly, due to overlapping service areas, some competing effects are observed (e.g., Yang et al., 2021). On a greater scale, the MaaS literature studies how micro-mobility and other NMS impact integrated transport systems, and vice versa. According to Arias-Molinares and García-Palomares (2020a), MaaS schemes require both a consolidated public transport system and a variety of shared mobility options. Results from Matyas and Kamargianni (2019) suggest that MaaS could encourage users to try NMS that they have not used before. On the other hand, public transport is valued higher when offered together with NMS in a bundle (Guidon et al., 2020). Ticket integration, as examples from bike-sharing schemes suggest (Fishman et al., 2012), can further potentiate the positive effect of shared micro-mobility on public transport usage. It is also expected that MaaS schemes decrease transport systems' overall travel time and cost (Becker et al., 2020).

The integration of informal transport services (also known as paratransit) – including minibuses and local three-wheelers – into MaaS has not yet been investigated in-depth, however. Similar to micro-mobility, informal transport often serves as a feeder to mass transit. It emerges wherever public transport services and infrastructure is lacking, and whenever excess capacity enables a profitable operation (Cervero and Golub, 2007). Previous studies have described the integration of informal transport into a (premature) MaaS scheme in India (Singh, 2020) and discussed the expected role of mini-buses within MaaS (Dzisi et al., 2022). These are important contributions to highlight the different circumstances for operating MaaS in the global South. The literature, however, is currently lacking case studies with empirical data to support these theoretical discussions and better understand the expected impact of MaaS on developing cities' transport systems. The present study aims to address this knowledge gap with an analysis on the supply side, thus complementing existing studies on user demand and potential adoption (e.g., see Chapter 4; Ye et al., 2020). In addition, this study also responds to general calls for more research on MaaS in developing countries (see Chapter 4; Dzisi et al., 2022).

6.3. Data and methods

6.3.1. Study area

Our study area is MM, the national capital region of the Philippines, located in Southeast Asia. MM comprises 17 cities and municipalities (Figure 6.1a) and is one of the densest and most congested urban areas in the world. Several reasons are said to contribute to the region's notorious traffic gridlocks such as the lack of both high-capacity transport infrastructure (Figure 6.1b) and integrated transport planning approaches. Another major reason relates to the lacking foresight in urban policies and land-use planning. Induced by high birth rates and internal migration from other parts of the country, population settlements have spilled into the periphery and outside MM's boundaries into the adjoining provinces. Travel times and distances in this monocentric region are therefore steadily increasing (Andong and Sajor, 2017). Since low-income neighborhoods in these areas are often underserved by public transport, this holds particularly for those without access to private vehicles (Abad et al., 2019). If first/last mile solutions would be implemented within a Maas scheme, it has been found that commuters would be willing to use public transport more often (see Chapter 4). This clearly highlights the suppressed demand in these areas and the need to respond to the described accessibility issues.

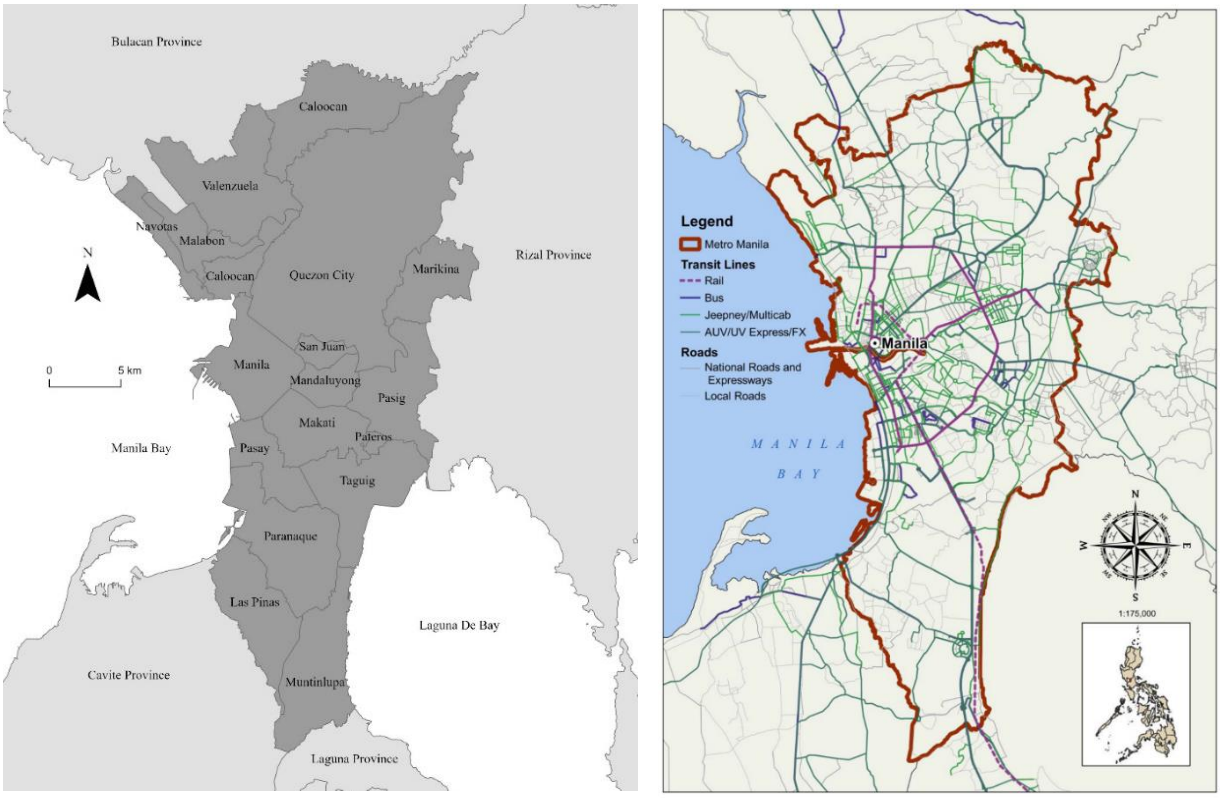


Figure 6.1 (a + b). Political map of the 17 cities/municipalities forming Metro Manila (left) and the region's public transit network (right)

Source: Roquel et al., 2021

Despite high motorization rates, vehicle ownership in MM is still relatively low. According to a large-scale transport study, about 90 % of households do not have access to private vehicles (NEDA, 2014). Hence, the majority of trips in the region is covered by public transport modes. Due to the fragmented rail network, there is a high dependence on road-based transit. In addition to buses and shuttle services (called UV Express), this mainly relates to the jeepneys – a local minibus version and the most dominant travel mode in the study area. The different transport services are regulated by several authorities in a decentralized way, and without consideration of a holistic transport planning approach. This has resulted in redundant and overlapping routes and disaggregated networks of the different transport services. The authors argue that the implementation of MaaS could be a potential solution to address these issues. Enabling seamless, intermodal trips in a fully integrated[20] transport system under MaaS – that includes public transport, informal transport, and various NMS – would thereby not only be a crucial ingredient to improve the access to public transit, but also to increase the quality of transport services as well as the network's overall efficiency and sustainability.

However, while ride-hailing apps (e.g., *Grab* and *Angkas*) enjoy great popularity in MM, more sustainable NMS are yet to be implemented on a larger scale. While privately owned e-scooters can occasionally be found on MM's streets, e-scooter sharing is still in its infancy in the region. Bike-sharing systems, such as the *UP Bike Share* at the University of the Philippines Diliman campus or the *Moovr PH* bike- and e-scooter sharing service in the Bonifacio Global City (BGC) business district in Taguig City and in the Makati City business district, are only available to small potential user groups and with fragmented infrastructure. MaaS is a mainly unknown phenomenon in MM as well, although a MaaS pilot is currently in the discussion/planning stage for the City of Pasig[21].

6.3.2. Data sources

In this research, we rely on three main data sources for our analysis. We use free and publicly available data that can also be obtained for many other cities worldwide (Table *6.1*), and hence our analysis could easily be carried out for other cities.

First, for the population raster and household locations, we use the World Settlement Footprint 2019 (WSF2019) data set. It provides a 10 m resolution (0.32 arc sec) global map of human settlements on Earth, building on optical and radar satellite imagery. More information on this data set, including the methods and its validation, is described in Marconcini et al. (2020). For the purpose of this study, we extracted the population raster for the MM region based on its political boundaries.

Second, we obtain the street network of MM from *OpenStreetMap* (OSM). OSM is a free editable geographic database of the world. The data is supplied by voluntary users based on a collaborative

[20] As suggested by Kamargianni et al. (2016), we consider that a full integration includes ticket, payment, ICT, and mobility package integration.
[21] http://www.solutionsplus.eu/pasig.html

mapping approach. The MM street network in OSM is continuously maintained by an active mapping community and therefore expected to be very comprehensive and up to date. For example, the data set includes a distinction between public (i.e., walkable for pedestrians) and non-public roads, which is relevant for this study.

Table 6.1. Overview of explanatory variables for the case analyses

Category	Data source	Data type	Year	Comment
Household locations	DLR/WSF2019	Raster data	2019	Available for all cities worldwide.
Street Network	OSM	Vector data	2021	Available for most cities worldwide.
Transit Stops	Sakay.ph/DOTr	GTFS	2014	GTFS data are available for many cities worldwide, usually made available by transport authorities or operators. Alternatively, the transit stops may also be obtained from other data sources (e.g., transport planning studies).

Third, the transit stops for MM are obtained from a GTFS (General Transit Feed Specification) data set. GTFS is a standardized data specification used by many transport authorities and operators worldwide. Its static component contains schedule, fare, and geographic information of the available public transport services. The data set for MM has been made available by *Sakay.ph,* a provider of a multimodal transport planner in the region, as part of a hackathon. Among others, it contains jeepney, bus, and train data from the Philippines Department of Transportation (DOTr, formerly known as DOTC Department of Transport and Communications) for the year 2014.

6.3.3. Measuring accessibility

We calculate transit accessibilities for the following scenarios: (1) the status-quo (baseline), as well as a MaaS-scenario in which (2) informal transport, (3) micro-mobility, and (4) both informal transport and micro-mobility are integrated.

In line with SDG 11.2.1, transit accessibility can be quantified as the proportion of the population with convenient access to public transport (buses and trains) within walking distance. The proposed maximum distance by UN-Habitat of 500 m can roughly be confirmed in the case of MM, despite the tendency that its citizens would even walk longer distances. Fillone and Mateo-Babiano (2018), using the Ermita district in the City of Manila as a case study, found that pedestrians (N=488) walk an average of 596 m per trip, while the measured distances range from 177 to 1,015 m. For significantly larger distances, citizens would rely on alternative modes of transport or (for unnecessary trips) not travel at all (Mateo-Babiano, 2016). Hence, in our calculations for the baseline, we consider the proposed **500 m** as the maximum walking distance to bus and train stops.

We follow a similar proxy for the calculation of transit accessibilities under MaaS and the integration of informal transport (Scenario 2), except that we additionally include the locations of the jeepneys stops.

For the analysis of Scenario 3 and 4, we expand the above definition and consider that public and informal transport services are not only accessible on foot but can also be combined with other modes and means of transport. As described in the background section, micro-mobility has become a popular option for multimodal travelers in urban areas, which is an opportunity to address public transit's first/last mile problem and increase its catchment area. Since comprehensive data on the use of micro-mobility in MM is currently not available, we rely on international data reported in the literature. According to large scale operational data from various service providers in Germany, e-scooters, on average, are used for trips up to approx. 2,000 m (Civity Management Consultants, 2019; cited in Laa and Leth, 2020), which aligns with findings from other case studies in different developed cities (e.g., Smith and Schwieterman, 2018).

In a trip data set from a bike-sharing scheme in Helsinki, Finland with 1.5 million trips by 41,700 users, the average distance traveled was 2.2 km (Willberg et al, 2021). Similarly, an analysis of 567,281 shared bicycle trips in Poznan, Poland shows that 81.5 % of all trips are made on short and medium distances (i.e., less than 3,000 m) (Radzimski and Dzięcielski, 2021). Hence, trips with shared bicycles are typically shorter than those with private bicycles (Willberg et al, 2021). This is due to the fact that, among other reasons, shared bicycles are indeed frequently used to complement public transport trips on the first/last mile (Levy et al., 2019).

These figures yet need to be validated in the context of a developing megacity, where shared micro-mobility options are currently not readily available, and where significant differences in terms of demographic and cultural characteristics, transport infrastructure, modal splits, travel behavior, and so forth are observed. Nevertheless, we argue that the international data reported in the literature is a good starting point to gain initial insights on a premature market. Accordingly, for Scenario 3 and 4, we regard **2,000 m** as the maximum distance for feeder trips to be covered by e-scooters and **3,000 m** for bicycles.

Hence, we calculate transit accessibilities as:

$$TA_i = \frac{\sum_{j=1}^{n} h_j \, f(d_{hpj})}{\sum_{j=1}^{n} h_j}, \forall i, j \quad (6.1)$$

with

$$f(d_{hpj}) = \begin{cases} 1 \text{ if } d_{hpj} \leq s \\ 0 \text{ otherwise} \end{cases}, s \in]0, k] \quad (6.2)$$

where TA_i is the transit accessibility index for location i. h_j denotes the households in location j. $f(d_{hpj})$ is a binary function of the distance threshold that takes values of 1 and 0, depending on whether the distance from household h_j to the closest transit stop p_j is within threshold s or not. k is the maximum distance of d_{hpj}. For the baseline and Scenario 2, s is set to 500. For the calculation of Scenario 3 and 4, it takes the value of 2,000 and 3,000, respectively.

The calculation was implemented with the *PtAC* Python package, a tool that was developed for the automated computation of the SDG 11.2.1 indicator (Nieland et al., forthcoming).

6.3.4. Research limitations

With regards to our research approach, two key limitations should be noted. First, some data limitations can be expected due to incomplete and/or outdated data. Although the WSF2019 data set builds on recent imagery data, we need to mention that population settlement patterns and urbanization in MM are subject to very dynamic developments. Also, it should be noted that the data set only provides an approximation of the household locations. Even though it leverages cutting edge technologies (e.g., the Copernicus satellites Sentinel-1 and Sentinel-2 for the radar imaging) and state-of-the-art machine learning techniques (Marconcini et al., 2020), inaccuracies naturally remain. Similarly, the GTFS data set does not represent the latest public transport information. Especially since the COVID-19 pandemic, there have been several route adjustments and the introduction of some new services (e.g., the EDSA Carousel busway). However, in this research, we only draw on the location of the transit stops. To the best of our knowledge, there have been little to none changes since the release of the data set relating thereto. Hence, we are confident that the data limitations only have a marginal effect on our study results.

Second, the SDG 11.2.1 definition has been critically appraised in the scholarly literature (e.g., Brussel et al., 2019). It is argued that this indicator does not capture a meaningful picture of the actual mobility situation on the ground. Indeed, it does only give an idea about the percentage of the population that resides within walking distance to transit stops, without accounting for common constraints to ride public transport (Fried et al., 2020). Especially in the global South, affordability and reliability of the services, safety and security concerns, crowdedness and comfort, unavailability during specific hours, the lack of travel information, among many other factors, can hinder the access to public transport. More recently, during the COVID-19 crisis, public health, social distancing rules, and the restriction of transport services have additionally contributed to uncertainties on this matter. Accordingly, we fully acknowledge that distance is only one of the limiting components of transit accessibility. For the reader to obtain insights on other comprehensive accessibility calculations, we refer to a recent review on this topic by Saif et al. (2019). Notwithstanding, we emphasize that the purpose of the SDG 11.2.1 indicator is to provide a simplified, universal, and globally applicable index for accessibility. Especially for the global South context, it is crucial that accessibility indices are obtainable despite possible data scarcity. In view of this, we argue that the SDG 11.2.1 indicator provides a meaningful proxy for transit accessibility which – as is the purpose of this study – can inform and guide relevant decision-makers and which is easily replicable to different contexts.

6.4. Study results

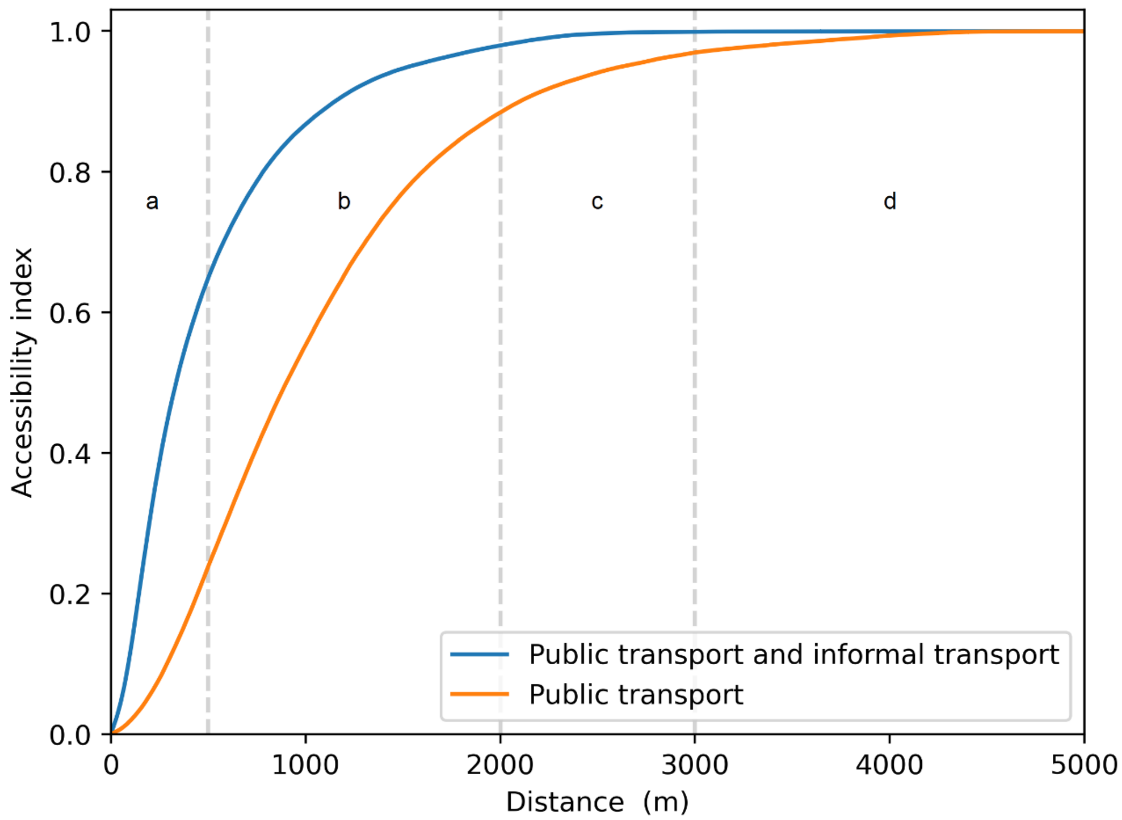
Figure 6.2 shows the accessibility index for MM under consideration of the different scenarios. A summary of the model results is shown in Table *6.2*.

For the baseline, we obtain a transit accessibility value of 0.239. Simply put, this means that only about 23.9 % of the MM population currently have convenient access to the public transport systems (i.e., bus and rail) within 500 m walking distance. This value is significantly lower than the official SDG 11.2.1 value for MM (0.325). The deviation can be explained due to the different underlying data sources[22]. For all households in MM, the mean distance to the closest transit stop is about 1,089 m, while the maximum distance according to our data is about 8,029 m.

In Scenario 2 – if informal transport would be adequately integrated into the transport systems – transit accessibility would almost triple to 0.650. The mean distance of all households to the closest transit stop would almost halve to about 564 m and the maximum distance decrease to approx. 6,765 m. In Scenario 3 – if micro-mobility is implemented as a feeder mode for public transport –

[22] In previous work, the calculation method used in the present study has been validated by means of a comparison with UN-Habitat data for 33 cities. It has been found that the results of this method very closely correspond to the UN-Habitat value (R^2=0.97) (Nieland et al., forthcoming).

transit accessibility would significantly increase to 0.884 (e-scooter) and 0.969 (bicycle), respectively. Almost the entire MM population (0.979 and 0.999, respectively) could even have convenient access to transit, if micro-mobility would be available as a feeder for both public transport and integrated informal transport on the first/last mile (Scenario 4).



a: accessible on foot; b: accessible via shared e-scooter; c: accessible via shared bicycle; d: not accessible

Figure 6.2. Transit accessibility index for Metro Manila

Table 6.2. Overview of model results

	Accessibility index			Distance to closest transit stop (in m)	
	walking	E-Scooter	Bicycle	mean	max.
Public Transport	.239	.884	.969	1088.96	8029.34
Integration of Informal Transport	.650	.979	.999	563.92	6764.56

The visualizations in Figure 6.3 give further insights on transit accessibilities in the region. It shows that the centrally located parts of MM (e.g., Manila City, Mandaluyong, and Makati) currently provide a significantly better access to public transport than cities located in the urban fringe (e.g., Valenzuela, Caloocan, and Muntinlupa) (Figure 6.3a). Due to the concentration of work opportunities (e.g., MM's three major central business districts, BGC, Makati CBD, and Ortigas) as well as educational, cultural, and leisure facilities, these areas generate much of the region's trip demand. Hence, most of the bus operation originates/terminates in the center of MM, either on radial routes to/from the adjoining provinces or along the circumferential EDSA highway, the most important and frequented road in MM. Also, most of the current rail line operation (LRT1, LRT2, and MRT3) does not exceed the center of MM. Although the distance to transit stops in these areas are the shortest in the region, many households still do not have access to buses and rail within walking distance. Residents in the periphery are even worse connected to the public transport systems, as the closest bus and train stops are often located in more than 2,000 m distance.

The integration of jeepneys into the transit network, in contrast, would create a much denser network (Figure 6.3b), especially in the central part of MM. Informal transport could thus contribute to enabling a convenient access to the transport systems within walking distance for many residents in these areas. The integration of shared micro-mobility could additionally connect those citizens that reside in more than 500 m distance to the closest transit stop. In addition, shared micro-mobility could also serve as an effective mode alternative, for example, for short business trips within the CBDs.

On the other hand, despite the integration of informal transport, rather low access to the transport systems would remain in the residential areas in the urban fringe. This includes both low-income, informal settlements as well as locally disembedded gated neighborhoods and wealthy subdivisions (Kleibert, 2018). In the former, vehicle-ownership is usually very low and residents often rely on local two- and three-wheelers (*habal-habal* and tricycles) to get access to the transport systems. In the latter, residents primarily depend on private vehicles. This can be explained due to the prevalent view of the private car as a status symbol, but it is also reinforced by the inconvenient access to the transport systems. The subdivision development has segregated these areas from the adjacent public road networks which unnecessarily prolongs walking distances to bus and jeepney stops.

For both informal settlements and subdivisions, shared micro-mobility could therefore significantly improve the access to public transit. The vast majority of the population in these areas resides within 500 and 2,000 m distance to the closest transit stop, which could conveniently be covered via e-scooter or bicycle.

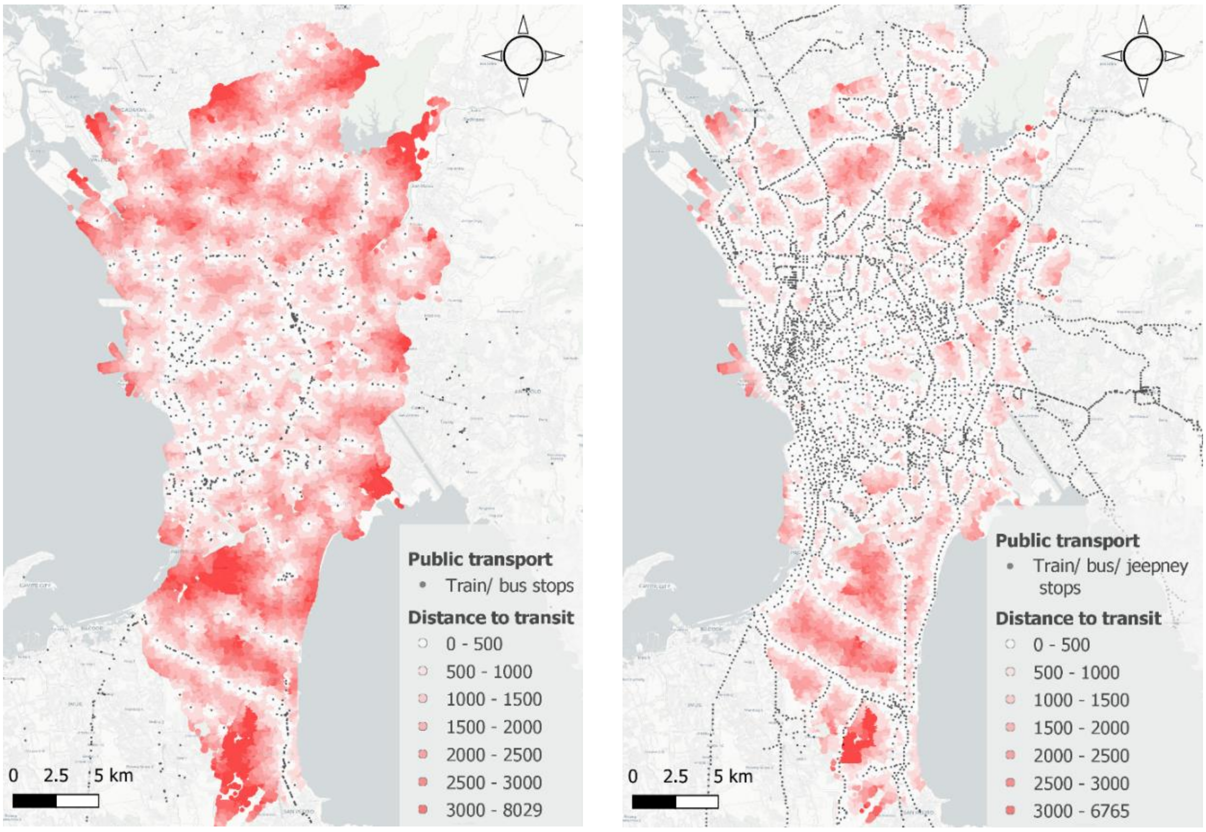


Figure 6.3 (a + b). Transit accessibilities in the Metro Manila region: status quo of public transport (left) and with the integration of informal transport (right)

6.5. Policy recommendations

In the previous section, we outlined where and to what extent accessibilities in MM can be increased under MaaS. However, it is crucial to note that the results merely indicate potential accessibility gains, if MaaS is fully implemented, informal transport fully integrated, and if micro-mobility options are widely available to users. Only if this can be realized, users can truly benefit from seamless, multi- and intermodal trips and better access to the transit network.

In the following sub-sections, we therefore use the empirical evidence from our analysis to derive policy recommendations that we discuss against the backdrop of findings from the scientific literature. Specifically, we describe two fields of recommendations (Table *6.3*) that cities and transport authorities can address to exploit the accessibility potential under MaaS: namely (i) anticipate MaaS and support transport integration; and (ii) plan and stimulate the use of micro-mobility.

6.5.1. Anticipate MaaS and support transport integration

A major stream in the MaaS literature focuses on governance issues and the role of the public sector. Insights from field trials and case studies, thereby, suggest that the public sector should take up an anticipating role[23]. For example, lessons from Finland – which is acknowledged as one of the pioneer countries for MaaS – show that public sector engagement can be a strong catalyst for MaaS development (Mukhtar-Landgren and Smith, 2019), but also that more supportive roles could enable an even quicker uptake (Audouin and Finger, 2018). Meurs et al. (2020) confirm that a supportive role of public agencies is vital for successful MaaS initiatives. Fenton et al. (2020) argue that this does not only relate to support on the local level, but rather that a multi-level governance is required. In this context, different governance approaches have been identified (Hirschhorn et al., 2019), which involve a set of hard (e.g., legislative reforms, operational contracts) and soft (e.g., public strategies, roadmaps, R&D programs) policy instruments (Mukhtar-Landgren and Smith, 2019). While these insights have primarily been derived from European context, we argue that the public sector should also anticipate the MaaS development in the global South (see Chapter 5). Indeed, market forces in the mobility sector tend to drive outcomes that are mainly profit-maximizing (Sareen et al., 2021). This was observed in the Philippines and other developing countries in the case of ride-hailing, where private sector leads have resulted in rather unsustainable transitions (Yuana et al., 2019).

Consequently, establishing a vision and a desired outcome under MaaS would be an important step for the government as well as the public transport operators and key MaaS stakeholders. We argue that this should be anchored at top-level within the national transport strategy. Hereby, the benefits of integrated transport and the promotion of multimodal travel alternatives (to the private car) should be clearly outlined. In the case of the Philippines, this was adopted in the NTP and its IRR that envision "safe, secure, reliable, efficient, integrated, intermodal, affordable, cost-effective, environmentally sustainable, and people-oriented national transport system that ensures improved quality of life of the people" (NEDA, 2020).

Subsequently, MaaS also requires specific regulation and policy reforms (Li and Voege, 2017). The MaaS concept uncovers conflicts related to the legal definition of public transport (Karlsson et al., 2020), government regulated pricing and ticket selling (Polydoropoulou et al., 2020), public procurement processes, subsidies, franchising of public transport services (Wilson and Mason, 2020), and overall competition in the land passenger transport market (Wilson and Mason, 2020). Legal

[23] In line with Smith et al. (2018), this either translates to a public-controlled (MaaS platform operated by public sector) or a public-private development (MaaS platform operated by private sector).

concerns also arise regarding liabilities, risk sharing, passenger rights (Pagoni et al., 2020), data privacy (Cottrill, 2020), and so forth. Even though these conflicts seem to be less critical in developing context (see Chapter 5), legislation changes and facilitating policies for MaaS are indeed inevitable. In this context, local authorities in MM, for example, are aiming at a reform of the current franchising model towards a service contracting program, which was budgeted under the General Appropriations Act of 2021 (Dela Cruz, 2021). Since all road-based transport services are currently operated without subsidies and quality control and depending on private sector initiatives, this can be considered an important step to foster more efficiently organized transit services that can serve as the backbone of a MaaS scheme.

Other barriers for the MaaS transition have been identified as the degree of centralization of transport authorities and subordinated agencies as well as their entrenched structure and slow decision processes (see Chapter 5). Institutional reforms and development are therefore as well needed. For instance, a horizontal integration of institutions could facilitate the implementation of large-scale transport projects such as MaaS and enable centralized planning. In the particular case of MM, the establishment of a transport authority at Metropolitan level is therefore recommended.

One of the key objectives of such agency should be the elimination of barriers to transfer between different transport services and thus enabling seamless trips. Besides the possible accessibility gains that have been described in this chapter, optimizing transfers helps increasing the attractiveness of the transit network compared to the private car (Garcia-Martinez et al., 2018). This can be addressed through transport integration which involves both soft and hard measures. For the soft integration, the key technologies such as smart ticketing systems, ICT infrastructure, APIs, and platform architectures need to be made available and fully developed (Hu et al., 2015; Surakka et al., 2018). With MaaS, various transport and mobility service providers have to disclose their data, adhering to standardized digital formats. Yet, the policy framework for open data and API standards is often lacking in developing cities. Same applies to ICT equipment in transport vehicles and stations, which is needed to enable ticket and payment integration and to provide real-time travel information. Note that in MM, for instance, all fares are based on single trips. Hence, this represents a major area where government intervention is crucial to direct policies and formulate the legal framework for enhanced ICT infrastructure including broadband deployment, and support for ICT research and development. Physical (built) transport integration, furthermore, contributes to a better travel experience and thus increases the acceptance of different transport services under MaaS. Multimodal transport hubs should therefore be established to coordinate and ease the transfer between different transport services and minimize transfer times.

6.5.2. Plan and stimulate the use of micro-mobility

Amid the pandemic and social distancing measures, micro-mobility emerged rapidly as an efficient solution to provide mobility to people in many developing cities. Despite the controversies as discussed in section 6.2, international best practices showcase how micro-mobility schemes – if matched with appropriate, dynamic regulation and built on a public-private partnership model – can be integrated in urban systems and enable just low-carbon mobility transitions (Sareen et al., 2021). Most importantly, enabling policies are needed to ensure safer space for lightweight vehicles and increase acceptance for micro-mobility as an alternative and complementary travel mode. In MM, the Land Transportation Office (LTO) has issued guidelines for the operation of electric light vehicles (Administrative Order 2021-039) that provide clear vehicle specifications (i.e., for e-scooter, e-bikes, etc.), as well as guidance on where (only on designated lanes) and how (defined speed limits, mandatory helmets, etc.) they can be used. However, the order restricts the operation to small local roads at *barangay* level (the smallest administrative unit). This significantly limits the range and makes many destinations inaccessible via such vehicles. Instead, a more permissive policy environment is recommended that supports a more equitable access to transport infrastructure (including for those without access to private cars) and allows potential operators to create a viable BM and provide quality service to meet the (growing) demand. Notwithstanding, regarding the parking of e-scooters, rather restrictive policies are advisable to avoid conflicts in public space allocation and to not adversely affect active transport (Laa and Leth, 2020). Parking should thus be limited to designated parking areas, so that e-scooters do not emerge as additional hindrances and impair the walkability of sidewalks/pathways (that in many developing cities are often not well developed and maintained). Moreover, even though free-floating shared micro-mobility schemes provide more flexibility and some accessibilities advantages (Brown, 2021), for a developing megacity such as MM, a station-based solution (with docking stations and/or bicycle racks) for accessing and returning shared e-scooter and bicycles is recommended. Regarding e-scooters, docking stations reduce interference in public spaces, increase acceptance, and allow the recharging of vehicles if needed. It also reduces the planning and operational complexity of such schemes (Chang et al., 2021), although it is argued that docked schemes are costlier (Brown, 2021). Docked micro-mobility schemes, nevertheless, require interventions due to supply imbalances and to steer the spatial distribution of vehicles (Brown, 2021), which can be addressed through dynamic pricing, gamification, and other incentives.

It is therefore imperative to analyze trip data to understand usage dynamics and spatiotemporal patterns of micro-mobility trips, which should be complemented by regular surveys on micro-mobility usage and demand. The insights from these analyses can contribute to a better understanding and the elimination of possible barriers to use micro-mobility, to avoid the substitution of active transport trips, and to identify the optimal locations for sharing stations. Although city centers represent lucrative locations for micro-mobility, our study has highlighted the accessibility potentials that micro-mobility can provide in the periphery and where public transit supply is lacking. To enable a feasible operation in these areas, policymakers need to create incentives for operators or subsidize micro-mobility trips. Furthermore, to promote micro-mobility as a feeder mode, sharing stations should be deployed in proximity to transit stops and terminals, as well as at shopping malls, manufacturing plants, recreation facilities, and other major trip generating locations.

Moving forwards, micro-mobility should be considered as an integral part of MaaS. This means that micro-mobility services should be locatable, bookable, and payable via the MaaS app. For trip requests, micro-mobility should be suggested as a travel alternative for short trips as well as a feeder for longer, intermodal trips. In addition to the “pay as you go” alternative, micro-mobility should also be included in mobility packages, if available. The included amount (either based on time or distance) should be defined in such way that micro-mobility can be established as an attractive alternative mode without cannibalizing active and public transport. It should furthermore be noted that preferences towards and demand for MaaS services are expected to change over time. Thus, mobility packages need to be constantly validated and may require adjustments and updates over time (Ho et al., 2018).

Due to financial and operational constraints, it should furthermore be noted that it is unlikely that sharing stations can be located in proximity to all households. It is therefore crucial to also encourage private ownership of micro-mobility through tax advantages, subsidies, or other incentives. Note that in MM, for instance, bicycle-owning households (36 %) already clearly outnumber those with cars (11.5 %) (Siy, 2022). Policies that aim at the integration of private micro-mobility and public transit should therefore have priority. For example, where feasible the opportunity to bring bicycles and e-scooters into buses and trains should be made possible. Also, sufficient bicycle racks and micro-mobility friendly infrastructure should be made available at major transit hubs and terminals. According to a recent study, private e-scooters (and e-bicycles) have a lower carbon footprint compared to shared vehicles (mainly because the higher utilization of shared micro-mobility does not compensate for the shorter vehicle lifetime) (Reck et al., 2022). Thus, usage of shared micro-mobility should in the long term ideally lead to ownership.

Moreover, it is crucial to introduce integrated transport planning approaches that consider micro-mobility and take the increasing multimodal travel behavior into account. This should be reflected in a fairer allocation of road space by planning additional micro-mobility lanes. Considering that safety is a major barrier for the uptake of micro-mobility (Sanders et al., 2020), urban and transport planning should aim at creating dense networks of safe and prioritized dedicated lanes. Previous studies highlight that e-scooter riders are willing to travel longer distances (59 % longer) if dedicated lanes are available (Zhang et al., 2021). Also, the positive impacts of cycling infrastructure investments on active transport have been well documented in the literature (e.g., Marqués et al., 2015). Moreover, well developed infrastructure can increase the perception of security (from crime), which in the context of the global South is an important aspect for first/last mile trips (Venter, 2020).

Table 6.3. Overview of policy recommendations

	Recommendations	Policy types	Required actions	Expected time for implementation
i	Anticipate MaaS and support transport integration	Legislative change and institutional reforms	- Develop a transport strategy that considers MaaS - Provide legal framework for MaaS operation - Enable the local planning institutions and authorities to plan integrated transport systems	mid-/long term
		Transport Integration	- Soft integration: a) Develop MaaS app; b) ticket and payment integration; c) ICT integration; d) mobility package integration	short-term
			- Carry out infrastructure developments for physical (built) transport integration	mid-/long-term
ii	Plan and stimulate the use of micro-mobility	Legislative change	- Create permissive policy environment for the use of micro-mobility	mid-term
			- Incentivize private ownership of micro-mobility	short-term
		Transport Planning	- Conduct demand analyses for micro-mobility (Where? When? How much?) and involve citizens and stakeholders - Implement shared micro-mobility schemes - Integrate micro-mobility into the MaaS scheme (as an alternative for multimodal travel suggestions, as part of the mobility packages, etc.)	short-/mid-term
			- Include active transport paradigm in integrated planning guidelines - Carry out infrastructure investments to enable safe and prioritized use of micro-mobility	mid-/long term

6.6. Conclusion and future research

This research has performed an analysis on transit accessibilities in MM under MaaS. Our results highlight the importance of informal transport today (hence, the need to integrate it), and the potential role of micro-mobility in the future. Through the integration of these transport services, areas that are underserved by public transport can be connected to the transit network, which is a promising way to address latent demand, compensate for lacking transport infrastructure, and help realizing transit accessibilities comparable to those found in developed cities with extended mass transit systems. However, we stress that both facilitating and regulatory policies are needed to exploit this potential and ensure a more equitable access to the transport systems in the long run. The benefits of MaaS in enhancing the accessibility to public transit could be more fully realized when policymakers view MaaS as an opportunity to advance the broader goals of sustainable development and when transport planning is integrated and cross-sectoral. The national governments are expected to create a level playing field for healthy competition and set the national roadmap for different infrastructure investments. We note that implementing the policies recommended in this research will require strong commitment to address the prevailing automobile bias led by minority elites (see Chapter 5), and thus promoting a paradigm shift towards people-centered urban mobility. While the past has shown that transport innovations and accompanying policies in the global South have often only been implemented hesitantly (Pojani, 2020), the COVID-19 pandemic has opened a 'window of opportunity' for MM and other developing cities to introduce unprecedented, structural changes, including transport reforms and transformations of incumbent regimes (see Chapter 3; Sunio and Mateo-Babiano, 2022). Indeed, in the immediate response to the crisis, significant shifts towards active mobility were observed, as well as shifts in policymakers' priorities towards protecting public health (Sunio and Mateo-Babiano, 2022). Consequently, many policy implementations (service contracting of public transport, cashless payment systems, etc.) and infrastructure investments (dedicated active mobility lanes, BRT, etc.) have been introduced that in the future may facilitate the implementation of MaaS.

Additional studies are needed to reinforce our findings and provide further insights. A deeper investigation on accessibilities (e.g., using methods as described in Saif et al., 2019) is needed to analyze other limiting components to access public transit in the global South. Moreover, the analysis should discriminate between different socio-demographic variables to understand (if and) how (in-)accessibility affects different segments of the population. An underlying challenge is the digital divide representing the gaps or the inequality in access to ICT and the internet. Low-income households may be isolated from internet-enabled NMS that could increase their access to public transit. Pangbourne et al. (2020), accordingly, highlight the challenge of social exclusion with MaaS' reliance on digitalization, recognizing it also might further exclude the unbanked. Future research should therefore focus on specific recommendations to address the digital divide and prevent transport inequalities. While our results provide an idea about the potential accessibility gains under MaaS, in reality, however, there are diverse financial and operational constraints that hinder the wide-spread deployment of sharing stations. Hence, future research should study the optimal location of n-number of sharing stations to maximize overall accessibility. Also, potential mode substitution effects of micro-mobility in developing cities should be studied, and especially if users would replace car trips. Finally, we recommend investigating the integration of other NMS that have not been considered in the present study (e.g., ride-hailing and car-sharing).

Chapter 7

7. Conclusion

Urban areas in developing countries are increasingly facing transport and mobility related problems including traffic congestion, accidents, and air and noise pollution. Policymakers must address these issues for social, economic, and environmental reasons. In addition to long-term infrastructure projects, they are seeking short-term and cost-effective solutions. The present dissertation is concerned with the question of whether MaaS – i.e., integrating different transport modes and making them accessible on a digital platform – represents a suitable approach in this regard.

The MaaS concept originates from Europe, where nowadays it is a widespread solution with several schemes established through private and public sector initiatives. In Chapter 2, we show that private sector actors are likely to carry the MaaS concept to the global South. We studied the diffusion of different NMS (ride-hailing, carpooling, and MaaS) that are based on the multi-sided platform business model and found that the internationalization of start-up companies serves as a proxy for the global diffusion of the respective NMS – typically, from developed lead markets into the developing world due to both the market leader's expansion and the emergence of followers. Indeed, due to their nature of intangible assets, platforms can adapt rapidly into new markets at lower costs. This type of growth is necessary as platforms create value through user transactions and because the more users a platform connects on both sides (i.e., the demand and the supply side), the greater the network effects and benefits for all users. Although the MaaS BM is not easily replicable, which decelerates the pace of internationalization, it can still be expected that MaaS providers have a great interest in entering the large markets of the global South.

At the same time, we also expect that the public sector will push the MaaS concept as enabling multimodal and integrated transport is often one of the key objectives of transport authorities. Moreover, as identified in Chapter 3, the COVID-19 pandemic has created a window of opportunity for a MaaS transition that the public sector should take advantage of. Using aggregated cell phone and GPS data, we analyzed mobility behavior during 6 months of lockdown in MM. Among the three transport modes under investigation (driving, public transport, and walking), public transport experienced the largest drop during the study period (−74.5 %, on average). This highlights that policymakers must prioritize public transport to enable a more equal access to transport by all population groups. As a data driven solution, MaaS could thereby deliver many benefits. For example, it could support a safe and phased reopening of public transport services, while generating much needed data for both informing time-sensitive decisions and long-term transport planning. It seems that due to the pandemic, policymakers indeed recognize the upsides of integrated transport and MaaS. Hence, several transport policies in favor of MaaS such as the establishment of an interoperable automatic fare collection system and the promotion of cashless payments have already been introduced in MM.

Also, users seem to be prepared for MaaS. In Chapter 4, we analyzed MM citizens' readiness for and attitude towards MaaS, and how a MaaS-system could influence users' mobility behavior through binary probit models. To this end, data was collected through an online survey that has been completed by 238 respondents. While the vast majority (84 %) of respondents stated they were likely to use a MaaS app, the main reasons for adoption appear to be reliability and cost savings. While the former can be achieved through the provision of real-time travel information and the suggestion of travel alternatives, the latter can be realized through MaaS mobility packages. It was also found that MaaS could benefit from the already very multimodal travel behavior in the region and citizens that usually combine different modes of transport to reach their destination. In addition, most of the respondents are also already using different transport apps such as ride-hailing or carpooling. MaaS could therefore be a suitable solution to consolidate these different services and make public transport more attractive and convenient. Our analysis thereby reveals that most respondents (61 % of the total respondents, corresponding to 73 % of the potential MaaS users) would indeed use public transport more often under MaaS, which indicates that MaaS has the potential to promote more sustainable travel behavior in MM.

In Chapter 5, we provide more insights on developing cities' capacities to plan and govern MaaS schemes. Considering that transport authorities frequently failed to implement innovative transport projects in the past, we aimed to shed light on possible implementation barriers. Following a literature review at the intersection of transport research and public sector innovation, we categorized the identified barriers according to the TOE framework. We then determined global South relevance through a two-round expert survey. Data related issues (e.g., the need for standardized open data) have been identified as the most critical barrier. Also, multimodal transport planning and coordinating intermodal trips seem to be crucial challenges, considering highly fragmented operator landscapes and the lack of integrated transport planning approaches. In addition, car-centric developments, current institutional setups, and transport authorities' organizational structures could hamper a MaaS transition in the global South. For a successful implementation of MaaS, transport planners and policymakers need to address highly interrelated barriers that include all TOE contexts. For example, they need to shift their focus from car-oriented approaches towards people-centered objectives. Also, it is necessary to better integrate informal transport services and to maintain open and constructive exchange with transport operators and other involved stakeholders. Eventually, institutional developments and reforms are needed to meet the requirements of managing large, integrated transport systems and processing big data from various sources.

Chapter 6 looks at possible benefits of MaaS for developing cities. In particular, we aimed at quantifying how integrated transport systems under MaaS may change accessibilities to transit – one of the key indicators to assess the performance of transport systems. For the operationalization, we followed a simplified definition proposed by UN that measures the share of the population with convenient access to public transport within 500 m walking distance. To calculate the transit accessibilities for the baseline and MaaS scenario, we leveraged open and global data sources (e.g., satellite imagery and volunteered geographic information on OSM), which makes our approach easily replicable for cities worldwide. For the case of MM, we found that the integration of informal transport (i.e., jeepneys) into the transit network could almost triple accessibility from 23.9 % to 65.0 %. The integration of micro-mobility (i.e., shared or private e-scooter and bicycles) as a feeder mode could further boost this share significantly (to 97.9 % and 99.9 %, respectively). To exploit this potential and foster a sustainable development under MaaS, we formulated the following evidence-based policy recommendations. First, the public sector should anticipate MaaS and support transport integration under consideration of sustainability goals. Second, it should stimulate the use of both private and shared micro-mobility by creating a permissive policy environment, investing in active mobility infrastructure, and adhering to integrated planning guidelines.

With the results mentioned above, we have thus achieved all research objectives in the respective chapters. Taken together, we can therefore conclude that MaaS is indeed a suitable solution to tackle existing transport problems in developing countries. Our results show that enabling MaaS is an opportunity for policymakers to promote alternative transport modes and create more efficient and sustainable transport systems. Under MaaS, travel information for all transport modes would be made available, users would receive suggestions for different travel alternatives, they could seamlessly combine different modes and means of transport, and pay cashless for the entire trip. This would benefit public transport in particular and make it more attractive. Without MaaS, travel information is often communicated through word-of-mouth. Especially for non-frequent riders, MaaS would therefore make it easier for commuters to reach their destination in the most efficient way (e.g., using the cheapest or fastest alternative). The integration of micro-mobility would further address public transport's first/last mile problem and make more destinations accessible. MaaS would likely also make public transport more tangible for digital natives that prefer to plan, book, and pay services online. Overall, MaaS could thus serve as a short-term solution in response to the car-centric developments of the past decades and the associated negative externalities of motorized individual transport. To elevate benefits, the MaaS development should also be accompanied by long-term infrastructure investments for high-capacity public transport and active mobility. In conjunction, this would contribute to tackling the most pressing transport challenges in developing countries such as traffic gridlocks, deteriorating environmental conditions, and transport inequalities. In this context, especially vulnerable population segments (often those without access to private vehicles) would benefit from MaaS, including low-income households, children, and the elderly.

Hence, the research conducted under the framework of this PhD project has profoundly contributed to the incipient body of knowledge on “MaaS in developing countries”. In particular, we contribute to the scientific literature by

- showing that and how the MaaS concept is likely to diffuse to the developing world,
- unfolding the existing demand and potential adopters for MaaS in developing countries,
- quantifying potential benefits of integrated transport under MaaS, and
- outlining policy recommendations for public authorities to govern MaaS and create more efficient and sustainable transport systems.

Nonetheless, we have to acknowledge some limitations of our research. At the time the PhD project was started, MaaS was still a new and mostly unknown mobility concept. There have not yet been any large, operational MaaS schemes, let alone any initiatives in the global South. This has posed some challenges in terms of data collection. For example, for our analysis on the demand for MaaS, we had to explain the MaaS concept and hypothetically ask respondents whether or not they would use such service. Although the use of stated preference data is widely employed in the current MaaS literature, these results need to be viewed with some caution. Similarly, for the quantification of benefits of MaaS, we had to make some assumptions in our models due to the paucity of available data from operational MaaS and micro-mobility schemes. We addressed these limitations following recommendations in the literature; however, they can only fully be resolved once first MaaS pilots are available in the region.

While the interest in MaaS in the global South is indeed rapidly increasing and first MaaS schemes being planned, this opens up massive opportunities for future research. In particular, we suggest that scholars address the following research questions.

(i) How do MaaS trials and pilots in developing countries affect mobility behavior and what are users’ WTP for single and bundled mobility services?

(ii) How can informal transport services – that are characterized by little to no public sector regulation and are owned and operated by private freelancers – adequately be integrated into the MaaS platform?

(iii) How to avoid a digital divide and make MaaS in the global South more inclusive so that all citizens can benefit from it? More specifically, how to include the unbanked and those without smartphones and access to the internet?

The insights to these questions will be of pivotal importance for the further development of MaaS and provide policymakers with the necessary evidence to create a permissive policy environment for MaaS.

The conduct of this PhD research has opened up several research opportunities for the author to continue and complement the results of this work. For example, we are currently aiming to expand our study on MaaS barriers. Note that the findings described in Chapter 5 relate to a conference paper and that we could only draw on a rather small sample of international experts. Meanwhile, it is possible to leverage existing MaaS pilots in the global South to get insights from real-world projects and collect data from a larger pool of experts that are directly involved in the implementation of MaaS on the ground (see **Fehler! Verweisquelle konnte nicht gefunden werden.**. Building on the results described in Chapter 2, we also want to contribute to a better understanding of the evolution and mechanisms of mobility platforms. During our analysis, we identified that successful mobility platforms aim to integrate other NMS into their app – and often even unrelated services such as food or parcel deliveries. In another ongoing work, we thus aim to shed light on the so-called platform envelopment phenomenon (Eisenmann et al., 2011) in the mobility sector and the resulting rise of "super-apps". Another major focus represents informal transport, which – as the author argues – is the designated backbone of MaaS schemes in developing countries. The author's ongoing work in this field is particularly motivated by finding ways to improve informal transport (i.e., making it safer, more reliable, and accessible), for example, through digital civic engagement and open data (Hasselwander et al., 2022c).

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