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STRONGER COMBINED

MaaS IN 2020: A REVIEW OF EXISTING RESEARCH AND ROUTES FOR THE FUTURE

Robert Boyer and Steven Sarasini, RISE

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	NAME AND SURNAME	ROLE IN THE PROJECT	PARTNER
AUTHOR(S)	Dr. Robert Boyer Dr. Steven Sarasini	Researcher Researcher	RISE RISE
REVIEWED BY			
APPROVED BY			

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SUMMARY

This report was composed as part of Stronger Combined – an international R&I project funded by Interreg to explore the role of combined mobility, primarily within rural regions and areas. As such, this report examines the academic literature on Mobility-as-a-Service (MaaS) to investigate the geographical and conceptual areas that are covered by existing MaaS research and those which have been overlooked, aiming to deliver insights that can 1) spur developments in rural areas; and 2) inform future R&I programming within the broader MaaS field. Hence in addition to the above aims, this report also identifies gaps and shortcomings in academic scholarship, making recommendations for future research. The main findings of this report are summarized as follows:

- MaaS is a concept forming in real-time. There is still much debate about the 'true meaning' of MaaS and the steps necessary to fully realize it.
- MaaS research is overwhelmingly focused on urban places and populations. Rural and suburban areas are severely underrepresented in existing peer-reviewed research. MaaS for special populations and purposes like riders with disabilities or tourists is also underrepresented.
- Authors of MaaS scholarship come from institutions in multiple countries, but 80% of articles come from seven countries: Sweden, Australia, UK, Netherlands, Switzerland, and Finland. These countries also tend to be the focus of MaaS research, although a sizeable number of articles are context-free (e.g. theoretical or conceptual).
- Existing experimental and pilot-based research shows that access to MaaS has a measurable influence on individuals' use of different travel modes, including a decline in personal vehicle use. However, multiple studies cast doubt on the ability of MaaS to displace personal vehicles completely.
- The individuals most likely to adopt MaaS are *mode agnostic* – they already use multiple transportation modes for daily travel and are not strongly committed to any single mode.
- Stated-preference surveys reveal that 10-15 percent of surveyed individuals are enthusiastic about adopting MaaS while another 30-40 percent are at least open-minded to the concept. The remainder are unlikely to adopt MaaS as currently conceived, for a variety of reasons.
- Subscription-based MaaS with multiple bundled transportation services faces many obstacles including the complexity of service agreements and low stated-preferences for mobility bundles (albeit with exceptions). Several papers recommend that MaaS initiatives advance incrementally by including a small number of service providers and/or pay-as-you-go rather than subscription payment.
- The governance of MaaS (i.e., the approach that different government entities take to making MaaS work) is critical. Different cities and public transit systems have approached MaaS governance in different ways. While there is no apparent "one-size-fits-all" approach, there is some consensus in the governance literature that enhanced data sharing, standardization, and participatory visioning processes have been and will continue to be important to the success of MaaS in the coming years.
- The COVID-19 pandemic presents challenges to MaaS as conventionally envisioned, but some experts see opportunities for MaaS with expanded service offerings or as a tool for transportation resilience.

1 INTRODUCTION

Stronger Combined is a project co-funded by the Interreg North Sea Region Programme that aims to resolve mobility and sustainability challenges by offering alternatives to private vehicle ownership in sparely populated areas. Project partners include public-sector authorities and research institutes from the countries of Belgium, Denmark, Germany, the Netherlands, Norway, Sweden, and the United Kingdom. Stronger Combined pilot projects focus principally on resolving transportation challenges in regions, or under conditions, situated outside modern transportation system "mainstreams". Examples include rural and low-density regions (e.g. Värmland county in Sweden, the Westhoek region of Belgium, the municipality of Skive in Denmark), polycentric urban regions without a strong transit core (e.g. Halland county in Sweden, the city of Rinteln in German, the city of Genk in Belgium), service populations with special needs (the Groningen-Drenthe region of the Netherlands), and rural regions with transportation needs related to the tourism industry (the Innland region of Norway, the Highlands and Islands of Scotland). These regions face special challenges in transitioning away from the dominance of low-occupancy vehicles.

Mobility-as-a-Service (MaaS) and similar concepts that facilitate the combination of multiple linked transportation services have been depicted as solutions to these special challenges. This literature review discusses the state-of-knowledge on MaaS. It draws from existing peer-reviewed literature to clarify what we know, what remains to be discovered, and what has been overlooked in published English-language MaaS research. The review is motivated in large part by the question: *to what extent does existing MaaS research address the particular needs of Stronger Combined pilot projects? What future research directions can encourage the broad adoption of MaaS or transportation systems that otherwise minimize the use of personal vehicles?*

We find that published articles on MaaS fall into a small number of categories including "users" (e.g. who is interested and/or willing to pay for MaaS?), "governance" (e.g. how can innovations in public institutions, collaborative constellations, and/or decision making structures encourage MaaS?), "simulation models" (e.g. what do computer model simulations tell us about the possible impacts of MaaS?), "theoretical issues" (e.g. how can we conceptualize MaaS developments?), "pilot reports" (e.g. what are the outcomes of MaaS experiments?), "case studies" (e.g. what can real-world observations teach us about possibilities for Maas?), and "miscellaneous" studies related to new technologies or research methods.

While research on MaaS has expanded in breadth and depth since 2015, it has largely ignored the contexts and special conditions represented by the Stronger Combined living labs. In short, published MaaS literature focuses predominantly on challenges and innovations in urban centers with an implicit focus on daily commuting and utility trips for able-bodied travelers. Research on MaaS in rural and tourist regions, in poorly connected places, or for populations with special needs is extremely rare. Furthermore, MaaS scholarship has emerged *from* – and with a focus *on* – a rather small number of countries. Given the highly context-dependent nature of transportation systems, expanding MaaS research to a greater variety of places and travel conditions will help inspire confidence for policy and public-private investment in new MaaS schemes.

1.1 THE NEED FOR MAAS

Growing dependence on personal vehicles in countries all over the world has contributed to an array of social and environmental problems. In the decade between 2008 and 2017, the number of passenger vehicles per person increased in every European Union member state except Denmark, Lithuania, and Latvia (Eurostat, 2019). Automobile dependency in cities has also contributed to deteriorating air quality, and efforts to mitigate air pollution are now required in most major European cities (European Air Quality Index, 2019). The outward physical expansion of urban regions, segregation of land uses, and adherence to the demands of a modern work day have left many commuters *little choice* but to drive a personal vehicle between their home and workplace, as well as to and from other destinations during the day (Ewing et al., 2003, 2007; Hamidi et al., 2015; Jeekel, 2016, pp. 17–18; Verma, 2015; Yang et al., 2017). At an even broader scale, automobile dependence is linked to climate change and its ensuing threats to safety and human wellbeing. While the recent COVID pandemic has resulted in less frequent travel and a concomitant reduction in climatic impacts, the pandemic itself cannot eradicate the need for a radical reorientation of passenger transportation in order to meet sustainability targets.

MaaS is one of several potential responses to growing automobile dependency. While there is considerable debate about the proper definition of MaaS (see below) there is a general consensus that it takes advantage of smartphone technology to connect multiple existing travel modes on a single platform. Whereas trip planning, ticketing, and booking for different travel modes like public transit, carshare, car rental, taxi, and bikeshare have traditionally taken place via separate media, MaaS attempts to increase the interoperability of travel modes so that individual travelers can seamlessly transition among different services as if they were using a *single* service.

In the past five years, research on MaaS has blossomed even though the number of fully operable MaaS services remains quite low. The emergence of knowledge-sharing networks such as the MaaS Alliance, alongside research funding from the European Union signal a broad willingness to understand the potential for MaaS. This report offers an overview of existing peer reviewed MaaS research, identifying knowledge gaps and smart practices from around the globe. The review is guided by the following questions: What geographical and conceptual areas are covered by existing MaaS research and which have been overlooked? How can future research ensure that MaaS is deployed in a comprehensive and inclusive way? What kinds of new knowledge are necessary to help expand and improve MaaS offerings around the world?

The following section summarizes the methods used to identify peer-reviewed research and offers a simple analysis of the geographic contexts and research foci of MaaS research published prior to July of 2020. Subsequent sections discuss the challenges of defining MaaS, research related to end-users (e.g., *who is interested in using MaaS?)*, MaaS governance, simulation model research, and a brief discussion about how the current COVID-19 pandemic has reshaped the conversation around MaaS and shared transportation modes, generally.

2 METHODS

The articles included in this review were identified by entering the terms “Mobility as a Service” and “MaaS” as search criteria in the research databases Scopus and Web of Science on 17 July 2020. No lower bound was specified for the time span as the concept and its associated terms have emerged in academic literature very recently. Initial search results generated from Scopus and Web Science yielded 110 and 202 records respectively.

Results were further narrowed as follow. First, only peer-reviewed articles published in English were selected. This eliminated most conference papers, policy reports, and gray literature. Second, book chapters that emerged in the search were typically either rudimentary introductions to the concept of MaaS written for an audience completely unfamiliar with the topic or replicas of existing peer-reviewed journal articles, and were thus excluded. Third, articles were included only if their primary research focus was MaaS – it’s antecedents, consequences, barriers, enablers, potential in particular places, and so forth. Article relevance was determined by reading the article’s abstract. Articles that referenced MaaS as a consequence, potential consequence, or a phenomenon associated some other emerging socio-technological trend were generally excluded. For example, articles whose principal purpose was to discuss autonomous vehicles, platform governance, smart cities, urban logistics, 5G, Internet of Things, or demand responsive transport (DRT) were excluded even if MaaS was mentioned as a complementary development or a possible consequence of these other trends. In some circumstances, articles with a primary focus on DRT were included if the article’s abstract mentioned modal interoperability or first/last mile challenges that imply connections among multiple transportation operators.

Search results from Scopus and Web of Science were merged, and replica records were eliminated. This yielded 67 total records including 32 from 2020 (Jan-July only), 18 from 2019, 13 from 2018, 2 from 2017, and 1 each from 2016 and 2015. Figure 1 illustrates the number of MaaS articles published per year. These figures likely underrepresent the number of MaaS-related papers in all of 2020 as the literature review considered papers published prior to mid-July of 2020. It is apparent and unsurprising that MaaS as a research focus has experienced strong growth in recent years, especially after 2017. Utriainen & Pöllänen (2018) use a similar search process with the same search terms for a review conducted in June 2018, yielding 20 journal articles and 11 conference papers.

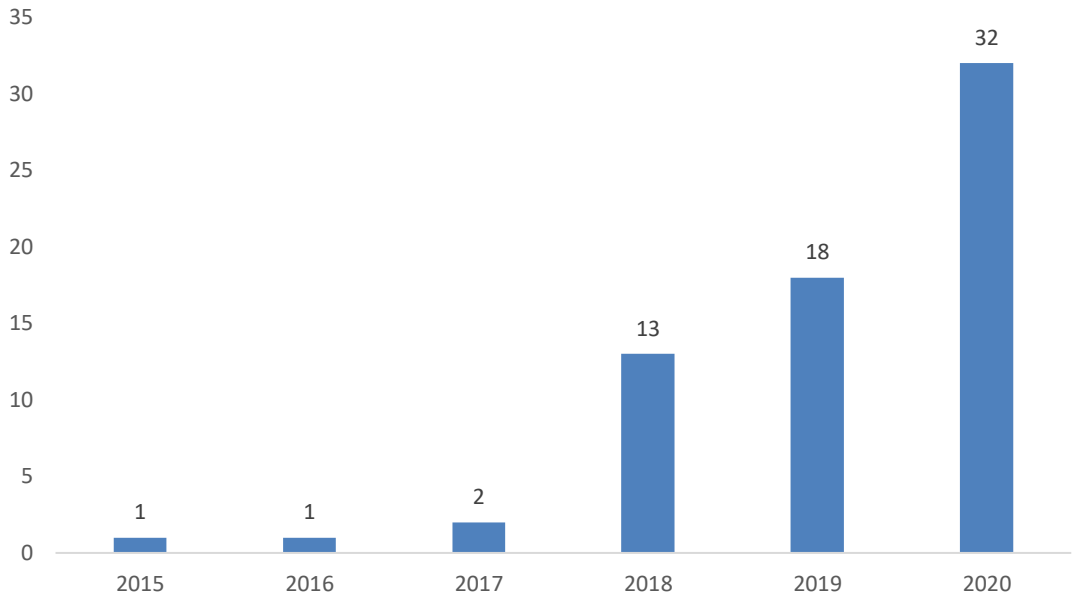

Figure 1: Number of peer-reviewed MaaS papers 2015- (July) 2020

Papers related to MaaS and the ongoing COVID-19 global pandemic were identified on an *ad hoc* basis due to the current and constantly changing nature of the situation. Such articles are omitted from the bibliographic analysis below.

2.1 MAAS RESEARCH SCOPE

Smith et al. (2018) categorize published research on MaaS into the following categories (paraphrased):

- Conceptualizations of MaaS and associated terms.
- Considerations of MaaS business models.
- Reviews of current conditions for MaaS developments and needed policies.
- Studies on the market potential and customer willingness to pay.
- Studies related to the UbiGO pilot in Gothenburg, Sweden.

This review adopts similar categories, drawing from published peer-reviewed literature to date. Each study was placed in a single category listed below, and where studies could conceivably fit into two or more categories, the paper was placed in the category that fit the *primary* purpose of the research article. Categories include *users* (n= 17); *governance* (n =14) ; *simulation models* (n = 2); *theoretical issues* (n=14); *pilot reports* (N=6); *case studies* (n=8) ; and *miscellaneous* (n= 6). New categories were generated from a pool of miscellaneous articles when three or more articles classified initially as “miscellaneous” shared a theme. Descriptions of each category and number of associated studies are detailed in **Error! Reference source not found.**.

Table 1: Scope of MaaS studies

Study types	Description	n
Users	Focuses on user perspectives, mode preferences, willingness to pay, often employing survey instruments and/or cluster analysis.	17
Governance	Answers questions about governance or the role of public policy in MaaS, often using key stakeholder interviews or surveys.	14
Simulation Models	Uses a simulation model to test hypotheses about the effect of MaaS on a transport system.	2
Theoretical Issues	Views MaaS from a new theoretical angle, offers critiques or suggestions about new ways to approach future scholarship or future applications	14
Pilot Reports	Reports related to on-the-ground applications and experiments with new services.	6
Case Study	Observes the situation playing out on the ground without it being a specific MaaS pilot or an experiment (e.g., no researcher intervention)	8
Miscellaneous	Other types of studies, for example international comparisons, methodological papers, studies that focus on challenges to MaaS in rural spaces	6

It is notable that a large proportion of existing literature is related to the *potential* of MaaS, removing barriers to MaaS, or the conditions that are necessary to elevate MaaS from a vision to reality. This is evident in the relatively low number of pilots or case studies that observe active MaaS projects.

2.1.1 GEOGRAPHY OF MAAS SCHOLARSHIP

Articles were classified by the spatial context of the research subject(s) – see Table 2. Papers that focused on urban contexts, whether specific cities or hypothetical urban spaces, were placed in an “urban case” category. A similar category labeled “urban respondents” includes studies that surveyed individuals living in (or with regard to) urban places. Some of these studies include individuals living in suburban places, however no studies include exclusively suburban respondents nor focus exclusively on MaaS in suburban areas. One paper makes an argument for enhancing MaaS services in suburban areas while relying empirically on urban case studies (Wright et al., 2020). This study was classified as an “urban case”. Combined, “urban” studies constitute 42 out of the 67 studies (62.6 percent). Three studies focus on large metropolitan regions that contain both urban and rural spaces, while only one study focuses on rural spaces exclusively (Eckhardt et al., 2018). A large proportion of articles (n= 21; 31.3 percent) were classified as “aspatial” because they focused on decontextualized concepts like technology, business models, transport psychology, choice modeling, or existing MaaS literature. Several papers situated at the national scale but with no discussion of spatial context or comparison to other nations were also placed in the “aspatial” category.

Table 2: Spatial context of published MaaS studies

Spatial context	Explanation	n
Urban case	Case study or analysis takes place in a city or urban region	34
Urban respondents	Analysis of respondents recruited from urban regions	8
Metropolitan regions	Case or participants recruited from large metropolitan regions that includes some rural areas	3
Rural focus	Case study or analysis takes place in rural areas	1
Aspatial	No discussion of space or place e.g. choice modeling, literature reviews, technology focus, business models.	21

2.1.2 ARTICLE ORIGINS AND RESEARCH FOCUS BY COUNTRY

Articles were also classified by the country of the lead author's institution and the country of research focus. Articles with authors from three or more countries or with research that focused on three or more countries were placed in special "multinational" categories. The results of this analysis are summarized in Figure 2. Sweden emerges as a leading country in both categories, with the most papers published by a lead author from a Swedish institution (n= 15) and the most papers focusing on a Swedish context (n = 11).

Sweden's lead in both categories is due in part to the Go:Smart Project in Gothenburg, Sweden, which piloted the first subscription-based MaaS service in 2014. Papers published by lead-authors from Australian institutions follow (n= 10), trailed by the United Kingdom (n=8), the Netherlands (n=7), Switzerland (n=7), and Finland (n=7). These countries also lead as subjects of research, however "No Country" papers that focus on decontextualized issues rank second (n=10) – immediately under papers with a focus on Sweden. "No Country" papers overlap somewhat with the "aspatial" papers discussed in the prior subsection, however there are several papers with a generic "urban" focus yet with no explicit country focus. Finland is the only country that is the subject of a higher number of studies than there are papers published by lead authors of the same country. Whereas studies with a Swedish focus are published *exclusively* by lead authors from Swedish institutions, there are as many studies published about Finland by lead authors outside Finnish institutions (n=4) as by lead authors from Finnish institutions (n=4). Canada, Greece, Singapore, and South Korea are 'pure exporters' of MaaS scholarship insofar as they are home to authors that write about MaaS, but no articles have been write about MaaS in these countries (at least peer-reviewed articles in English). Meanwhile, Austria and Denmark are 'pure importers' of MaaS scholarship as they have been the focus of MaaS research, however without lead authors from institutions in those countries.

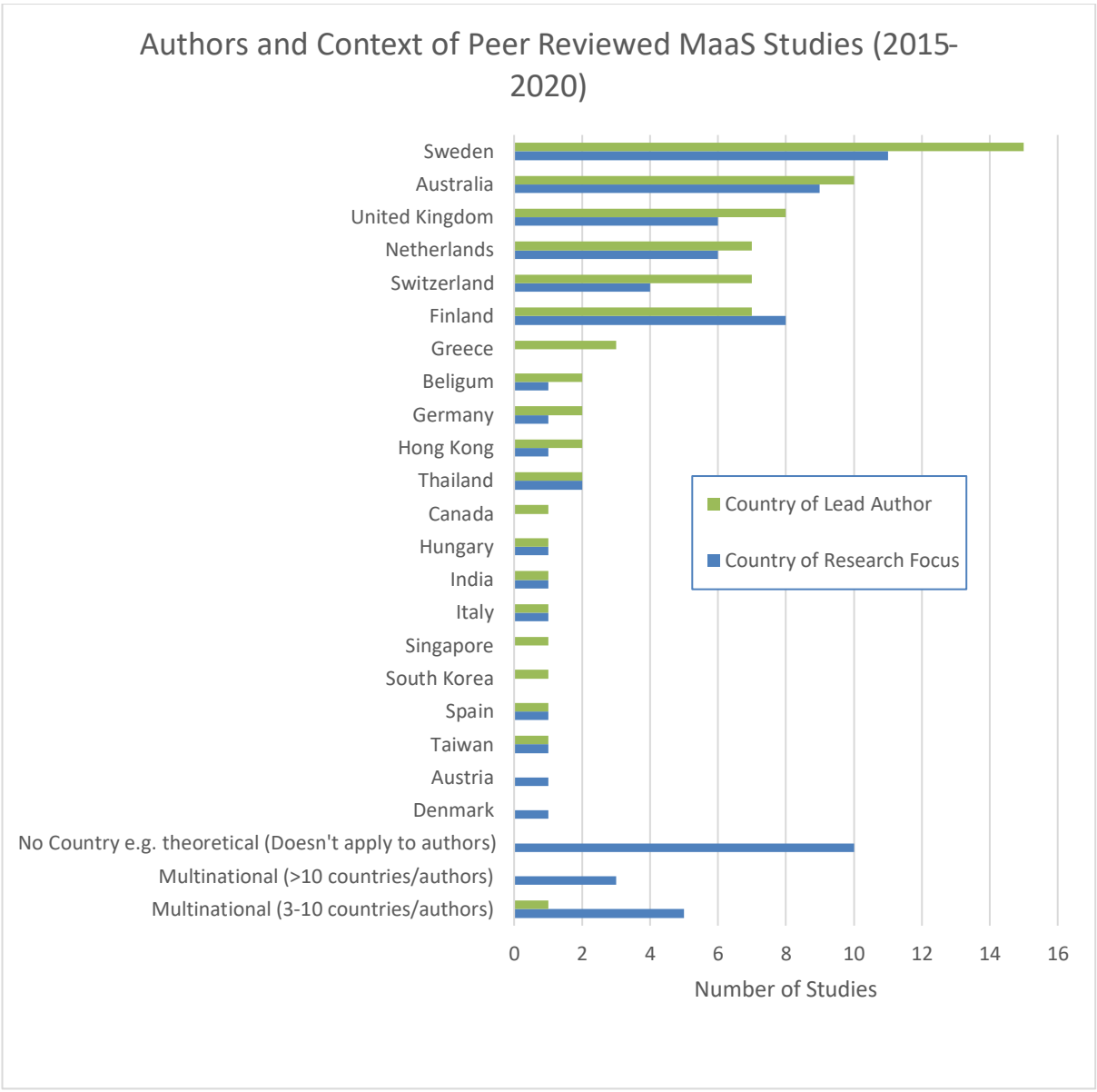

Figure 2: Lead author institution and national context of peer-reviewed MaaS studies (2015-2020)

3 DEFINING MAAS AND OTHER CHALLENGES

Existing MaaS literature devotes substantial attention to defining a contested and unsettled concept. This is understandable given (a) the relative youth of MaaS as a concept, (b) variations in MaaS across places and (c) overlap with emerging concepts like demand-responsive transportation, combined mobility, intelligent transportation services, shared mobility, smart cities, etc. Pickford & Chung (2019) comment:

"…there are probably as many definitions of MaaS as there are pilot schemes globally. This is probably the result of rapid evolution, the continued search for (and competition between) business models, power balance between stakeholders, degree of private sector participation, and local regulatory provisions" (p. 219).

Gaps in knowledge about MaaS' ability to deliver its envisioned societal benefits appear to have been filled – to some extent – by "speculation" informed by "strong emotional ideology" (Wong et al., 2020). A recent review by Calderón and Miller (2020) distinguishes MaaS from other emerging mobility services, defining it as "…a centralized platform that gathers all services and allows users to interact with, pay for, and choose among one or more of them" (p. 314). Similarly Smith et al. (2018) acknowledge many different existing definitions of MaaS, but constrain their analysis to "bundled offerings that facilitate intermodal use of [public transportation] and other transport services (p.593)". Several recent discussions temper depictions of MaaS as either "revolutionary" or a "new transport paradigm," characterizing it instead as an "evolutionary" extension of ongoing trends in mobility integration (Lyons et al., 2019) and "a new service model that can entail or embrace new travel behaviors"(Smith & Hensher, 2020, p. 56), respectively. Emphasizing MaaS as a medium for bringing multiple transportation services together, Smith & Hensher (2020) define MaaS as a "type of service that through a joint digital channel enables users to plan, book and pay for multiple types of mobility services" (p. 56).

One oft-heralded expectation of MaaS is that it will help individuals overcome the conventional hurdles of transitioning among multiple transportation options. Fully implemented, MaaS will allow a traveler to plan, pay for, reserve, and validate tickets for a variety of public and private travel options using a single mobile application. Ideally, the functional integration of multiple travel options through such an application will help households transition away from the dominance of personal motor vehicles. These aspirations were fueled in part by the Go:Smart experiment. Data collection before, during, and after the study found that participants reduced or eliminated their use of private motor vehicles while increasing their use of carsharing, private bicycle, and all forms of public transit (Sochor et al. 2016).

While the precise contours of MaaS vary from place to place and over time, it is perhaps useful to understand MaaS as a topology of increasing functional integration. A MaaS topology (Figure 3) developed by Sochor et al. (2018) describes MaaS from Level 0 to Level 4. The four levels are summarized here:

Level-0 MaaS involves no integration and separated mobility services as is common in most urban regions today. Different mobility services operate in functional silos, and planning, payment and ticketing all take place via media that are independent of other transport modes.

Level-1 MaaS involves the integration of *information* about different travel services (but not ticketing or payment). Services like Google Maps, the mobile app Waze or City Mapper all offer integrated information about different travel options. Such apps offer the ability to link directly to a user's ride hailing or shared mobility apps

when they select these trip options, but this functionality resides in separate mobile applications.

Level-2 MaaS includes integrated booking and ticketing for individual trips. Combined with capabilities from level 1, a level 2 MaaS service would allow an individual to plan a trip, and reserve and pay for tickets for that trip using a single mobile app. Integration is accomplished through a third-party broker that takes responsibility for ticket sales, but not for service delivery, which is accomplished by individual mobility companies. Within the mobility market, the Nordic operator Kyyti currently operates at level 2. Denmark's *Rejseplanen* website allows users to plan multimodal trips across the country and purchase tickets for individual trips on some services.

Level-3 MaaS involves integration *of the entire service offer* and focuses on the comprehensive, day-to-day needs of a traveler and their household. Level 3 MaaS is imagined as a sort of mode of transportation all by itself – a full alternative to the personal vehicle, serving the client-traveler for more than a single trip. Level 3 MaaS involves a MaaS *operator* responsible for bundling and repackaging multiple services. To date there have been two well-documented implementations of level-3 MaaS: UbiGO (Sweden-based) and Whim (Finland-based).

Level-4 MaaS involves the integration of *societal goals* into MaaS services at levels 0-3. In principle, level four describes the extent to which MaaS services fulfill societal goals that are typically linked to transport and mobility, including environmental and transport policy goals, urban development plans, regional accessibility policies, and so on. In practice, societal goals vary in time and space such that MaaS services must be tailored to local conditions. The fulfillment of these goals can occur in numerous ways, for example through public sector intervention, including infrastructure, land use planning, and tax incentives or subsidies to encourage servitized mobility while discouraging personal automobiles. However, MaaS may fulfil societal goals without public sector intervention. If a MaaS service deploys electric vehicles as a means to reduce operating costs, for instance, then it may serve to reduce emissions regardless of whether the state introduces some or other steering instrument or policy. Alternatively, a MaaS operator that significantly reduces private car ownership and/or use by offering a ridesharing service may help to reduce congestion. The classification of a level four MaaS service typically requires sustainability assessments that evaluate the way in which a particular service influences, among other things, travel behavior.

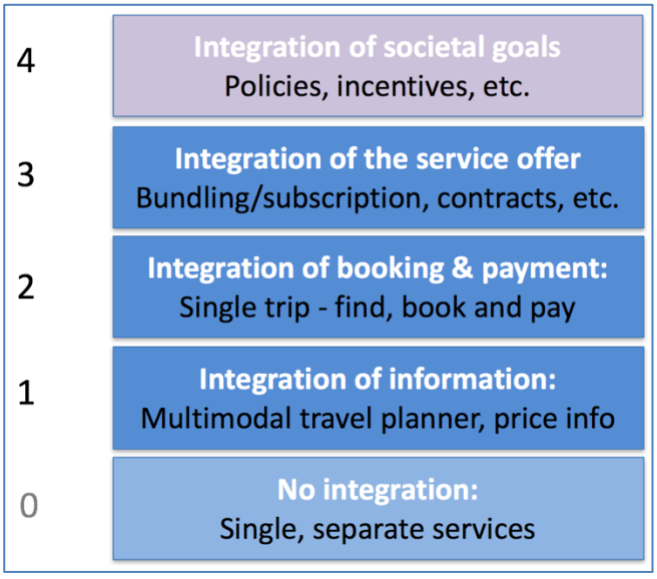

Figure 3: The MaaS topology

There is a general (and yet unproven) belief among MaaS practitioners that MaaS services at level 2 and 3 proffer the most attractive solutions for individual travelers and that these levels of integration are necessary for significant changes in travel routines and behavior. By contrast, services at levels 0 and 1 may be viewed as appendages to the existing transportation system that do not bring about any real change. As such, in what follows we focus on MaaS scholarship that examines services from level 2 and above. As will be discussed in other sections of this paper, attempts to implement Level-2 or Level-3 MaaS have encountered multiple challenges, including precarious institutional puzzles, fragile business models, and the perseverance of incumbent mobility regimes. Circumventing such challenges may require more incremental attempts to initiate MaaS – for example, beginning with two-mode offerings or beginning with pay-as-you-go payment options – in order to avoid the complications involved in reaching agreements suitable to multiple carriers (Pickford & Chung, 2019; Polydoropoulou et al., 2018).

4 SIMULATION MODEL RESEARCH

A small number of studies have applied simulation models to test assumptions about MaaS, offering insight into MaaS's potential influence on dynamic social and environmental variables that are challenging to measure, with or without the actual implementation of MaaS. Becker et al. (2020) explore the welfare impacts of shared mobility and MaaS in a simulation model of the city of Zurich, Switzerland. The model estimates that MaaS can lower transportation-related energy consumption by 25 percent, and that the effects are strongest when more shared modes are introduced, especially when dispatched to rural areas where public transit less accessible. The authors also warn that accomplishing energy savings through shared modes may require public subsidies of (currently private) rideshare and carpooling services – an argument that emerges in other research (Mulley et al., 2020; Wilson & Mason, 2020).

5 MAAS RESEARCH FOCUSED ON END-USERS

Recent MaaS scholarship is candid about the challenges inherent in changing individuals' travel routines, which are notoriously sticky. This is evident in results from both pilot studies and state preference surveys. A two-and-a-half month pilot in Ghent, Belgium offered 100 car owners mobility budgets of €150-350/month to spend on mobility services, other than their personal vehicles (Storme et al., 2020). Participants were asked to book their travel in a prototype mobility app combining a variety of car sharing, car rental, taxi, public transit, bike rental, and round-trip bike sharing services. While personal car use declined dramatically, no participant was able to avoid using their personal vehicle completely during the pilot period, although many car trips were displaced by private bicycle. Participants were especially likely to use their own cars for trips *outside* their daily routine. Similar results were found by Sjöman et al. (2020) in Stockholm.

In experiments that allow respondents to generate customized transportation service bundles, individuals tend to replicate their existing travel patterns (Ho et al., 2018, 2020; Mulley et al., 2020; Schikofsky et al., 2020). When offered opportunities to choose between different mobility bundles, respondents more often prefer packages that include modes of transportation they regularly use (Matyas & Kamargianni, 2019b), or simply stick with the *status quo* (Feneri et al., 2020). Individuals appear to take comfort in their daily routines, and face uncomfortable realities when their existing habits are framed in a new way. An in-depth study of Stockholm

travelers shows that individuals rarely examine the true costs of driving a personal vehicle once they have settled into an affordable monthly routine (Sjöman et al., 2020). MaaS – as currently conceived, and without public subsidies – might discourage customers by illuminating through alternative billing structures the true unit costs of using an automobile (e.g., in the form of carshare or car rental). Whereas traditional personal vehicle ownership allows individuals to segregate the costs of owning, fueling, repairing, parking, and insuring a vehicle, a servitized mobility scheme may encompass all of these costs in a single payment, which can dissuade potential customers even though the overall cost of MaaS is potentially much lower.

As a supplement to the small number of opportunities to observe MaaS in full operation, researchers have used stated-preference surveys, choice experiments, and cluster analysis to predict who would be most likely to adopt MaaS, and in what circumstances. While these studies sample populations from a variety of urban contexts, they show consistently that a substantial proportion of the traveling public are *at least* unopposed to the idea of MaaS. Such studies also consistently identify user segments that are (A) highly motivated to adopt MaaS, (B) open-minded about adopting MaaS, (C) unlikely to adopt MaaS for nuanced reasons, or (D) categorically uninterested in adopting MaaS.

- Alonso-González et al (2020) find that 32 percent of a nationally representative Dutch sample fit in a "MaaS-FLEXI-ready" (very likely to adopt) cluster while an additional 22 percent fit in a "mobility neutral" category that is open to MaaS. Meanwhile, a more focused case study in the Netherlands finds that 18 percent of participants fit into a highly motivated category with another 30 percent somewhat open to the concept (Fioreze et al., 2019).
- Liljamo et al. (2020) use a nationally representative Finnish sample to find that 43 percent are willing to state a price at which they'd adopt MaaS, while others in the study were either unwilling to respond (31 percent) or were opposed to the opportunity (26 percent).
- A large-sample (n= 4,000) Australian study found that "MaaS Enthusiasts" (with an 87 percent probability of adopting MaaS) constituted 14 percent of the sample, while another 7 percent of the sample had a greater than 50 percent chance of MaaS adoption (Vij et al., 2020).
- A study with 252 respondents in the region around Sydney, Australia estimates that 47.2 percent of the population would subscribe to MaaS with 36.2 percent choosing a pre-defined mobility package and 11 percent selecting a pay-as-you-go option (Ho et al., 2018).

Respondents that express a willingness to adopt MaaS tend to be younger, on average, than the sample population (Alonso-González et al., 2020; Liljamo et al., 2020[1]; Schikofsky et al., 2020), however the influence of other demographic variables like gender and education are inconsistent across studies. Incumbent travel behavior appears to be a reliable but nuanced predictor of expressed willingness to adopt MaaS. In multiple studies, the most likely MaaS adopters are *mode-agnostic* travelers – individuals without strong commitments to any particular mode of transportation. Feneri et al. (2020), for example, find that MaaS is most popular among individuals that are least committed to their primary mode of transportation. To the extent that monthly mobility expenditures represent a commitment to existing transportation routines, Liljamo et al. (2020) reveal that individuals who spend the least money on travel each month express the highest willingness to pay for

[1] Younger people appear to be willing to pay slightly more for a mobility package, but the difference is not statistically significant.

MaaS.

Ho et al. (2018) find that the user segments *most likely* to adopt MaaS are individuals who drive a car 3-4 times a week and those who drive 1-2 times a week, while individuals who *never* use a car or use a car *very frequently* (5-7 days a week) appear least likely to adopt MaaS. The authors confirm their findings in the city of Tyneside (UK), where they conclude that MaaS is best marketed as a substitute for a household's second car rather than as a total replacement for either public transit or personal vehicles (Ho et al., 2020). Correspondingly, Matyas (2020) identifies that London travelers classify different transport modes as "essential," "considered," or "excluded," and that the second category offers a window for MaaS to yield a substantial contribution to modal shifts.

The adoption of MaaS has also been framed through theories of psychology. In a sample of 1,067 German respondents, Schikofsky et al. (2020) find that individuals are more likely to adopt MaaS if they perceive that it stimulates "basic psychological needs" like *autonomy* over mobility choices, *competence* in navigating a mobility system, and *relatedness* to others. This corresponds with calls from scholars to integrate theories of social psychology into future MaaS research (Tomaino et al., 2020). Among other proposals, the authors warn that perceived loss of control (e.g., to an algorithm) over travel options risks reducing individuals' willingness to adopt MaaS, but that a well-tailored algorithm could simulate perception of control through very detailed customizable travel preferences.

Several studies test how different types of MaaS subscriptions attract or repel potential users. The underlying assumption is that the success of MaaS hinges on well-calibrated pricing and subscription periods. Liljamo et al. (2020) find that individuals are, on average, willing to pay €137 for a monthly package designed to meet their current mobility needs through public transit, taxi services, and car sharing. This amount is less than half the cost of a monthly package of Whim – an existing MaaS service, leading authors to conclude that MaaS services may have to initially build customers' trust and familiarity through lower-risk pay-as-you-go packages. In a London-based choice experiment comparing the desirability of different mobility packages, Matyas & Kamargianni (2019) find that the availability of public transit options increases the desirability of MaaS plans, while the presence of all other transportation modes (bikeshare, carshare, taxi) decreased the desirability of MaaS plans. The authors attribute this, in part, to the comprehensive coverage of public transit in London. Similarly, Guidon et al. (2020) find that respondents in the Zurich, Switzerland region express higher willingness to pay for public transit, carsharing, and park-and-ride services when they are included as part of a bundled offer, but that individuals are willing to pay more for bike sharing, e-bikes, and taxi when they are offered *a la carte*. The authors conclude that "subscription based pure bundles may not be the optimal strategy for mobility providers," corresponding with findings by Pickford & Chung (2019) that MaaS may have more success if developed incrementally rather than as a comprehensive bundle of transportation options.

6 GOVERNANCE OF MAAS

MaaS is (by several definitions) an inherently multi-actor undertaking. It is the consequence of multiple, separately owned and operated transportation services agreeing to offer their services with integrated information, payment, or ticketing services. The development of MaaS also involves actors *other than* transportation service providers, for example software developers, labor unions, parking authorities, funding

agencies, transportation infrastructure authorities, telecommunications companies, national legislatures, transport ministries, etc. As such, MaaS cannot be willed into existence like a traditional government service or a private enterprise. The governance of MaaS – how different public and private societal actors use formal and informal mechanisms to facilitate (or impede) the development of MaaS – is therefore essential to the field of inquiry.

Governance case studies are often filtered through systemic innovation frameworks like the multilevel perspective of sociotechnical systems (c.f. Audouin & Finger, 2019; Fenton et al., 2020; Hirschhorn et al., 2019; Pangbourne et al., 2020), neo-institutional theory (Karlsson et al., 2020, 2020; Mukhtar-Landgren & Smith, 2019), collaborative innovation theory (c.f. Smith & Hensher, 2020), open innovation (c.f. Smith et al., 2019), theories of alliance formation (c.f. Meurs et al., 2020), business model innovation theory (c.f. Polydoropoulou et al., 2020), and Bulkeley & Kern's (2006) governance framework for climate change (c.f. Audouin & Finger, 2019). These theories unite around an understanding of innovation as a complex multi-actor process over which no individual authority exercises complete control.

Broadly, the recent governance literature surrounding MaaS examines the role public authorities have played in specific MaaS pilots (Audouin & Finger, 2019; Fenton et al., 2020; Hirschhorn et al., 2019; Mukhtar-Landgren & Smith, 2019), the emergence of new intermediary actors (Smith et al., 2020; Wong & Hensher, 2020), potential policy frameworks (Smith & Hensher, 2020), and stakeholders' views on next steps (Polydoropoulou et al., 2020). More than other streams of MaaS scholarship, this literature relies on case studies of actual attempts to forge MaaS and often uses interviews with public- and private-sector actors as a data collection method. Finnish and Swedish case studies figure prominently, although not exclusively. Of the studies have been published on these cases, a number denote the various drivers or and barriers to the full implementation of MaaS (Kamargianni et al., 2016; Karlsson et al., 2020; Smith, Sarasini, et al., 2019; Smith, Sochor, et al., 2019; Sochor et al., 2015; Strömberg et al., 2016, 2018; Surakka et al., 2018) . These studies have identified a range of dynamics that occur at a national or international (macro) level; at a (meso) level of networks and business ecosystems; and at a (micro) level that describes individual travelers, their attitudes, behavior and preferences.

6.1 MACRO-LEVEL DYNAMICS

Macro-level drivers of MaaS developments include a set of global megatrends – a set of pressures that can be felt acutely across different parts of the developed world, and which forcefully require changes to existing transportation systems. Megatrends include 1) policy agendas at every level of government to redress climate change; 2) urbanization and sub-urbanization, which contribute to congestion, poor air quality, and infrastructure problems; and 3) pressures mobilized via key stakeholders to the transportation system, such as research organizations and different elements of the public sector (e.g., national government committees, provincial and municipal city officials, transport agencies). These stakeholders see MaaS as an opportunity to bring about a sustainable reorientation within passenger transportation, noting that MaaS can boost the economy (via new innovative cycles and job creation), generate environmental sustainability improvements (e.g., reduced emissions and congestion, improved urban air quality, resilience) and contribute to the social aspects of transportation (improved accessibility, social inclusion, affordability).

In some European countries such as the Netherlands, Finland, Scotland and Sweden, stakeholder interest has resulted in ambitious visions and plans, supported by R&I programs that seek to trial and evaluate the MaaS

concept through pilots and assessment frameworks. The importance of vision planning appears consistently across the MaaS literature. Visions are effectively works of plausible fiction, deployed to convince actors that some heretofore impossible or unimaginable task is, in fact, possible (Hopkins, 2007). Visions are not necessarily intended to manifest precisely as they are articulated. Instead, they engage actors in a planning process by "emplotting" them – framing them as characters in an emerging narrative (Goldstein et al., 2013). Such a tool is arguably critical in the process of spurring a rather novel concept with little precedent to existing market data. Citing the many social and economic uncertainties of MaaS, Pangbourne et al. (2020) argue, "New mobility concepts like MaaS require more envisioning rather than forecasting approach in development of future strategies, as there is a lack of evidence as to how such a service will change mobility practices (p.46)". Multiple articles invoke the "strong vision" of Finland's Ministry of Transport and Communications as an important catalyst for MaaS (Karlsson et al., 2020; Mukhtar-Landgren & Smith, 2019). Audouin & Finger (2019) invoke the collaborative visioning process led by the City of Helsinki and ITS Finland as an important ingredient in the success of the Whim application. An inclusive, region-wide visioning process is perhaps an appropriate prescription for the case of Madrid – a city that has been flooded by shared mobility services since 2010. The region is currently home to three different and disconnected MaaS initiatives that could benefit from a governance framework that facilitates standardized data and interoperability, impact evaluation, and governance of the system overall (Arias-Molinares & Carlos García-Palomares, 2020). Studies also comment on how the *lack* of vision at different levels has slowed progress in Sweden (Karlsson et al., 2020; Smith, Sochor, et al., 2019) and that failure to arrive at a shared vision has delayed progress in Vienna (Audouin & Finger, 2019).

With regard to other macro-level barriers to MaaS developments, existing national transport codes and EU directives that outline definitions of public transportation and prescribe the types of roles that can be taken by public transport operators are seen to require revision to facilitate new forms of public-private sector collaboration. Further noteworthy barriers are state aid rules and procurement legislation, which limit the ways in which public transport can cooperate and partner with private MaaS providers. The novelty of the MaaS concept has also resulted in uncertainties related to existing regulatory arrangements within the public sector, which were designed prior to the emergence of MaaS. For example, there is a distinct difference in the way that EU directives that dictate the role and mandate of public transportation in MaaS initiatives in countries such as Sweden and Norway. Finally, varying levels of value-added tax for different types of mobility services, creating an unlevel playing field among individual service providers.

6.2 MESO-LEVEL DYNAMICS

At the meso level, drivers relate to factors that influence different types of transport providers, among whom MaaS is generally viewed as a significant innovation and business opportunity. The development of new business models that capture the value inherent in collaborative consumption; multi- and intermodal travel; and big data analytics are what underpins this view. Further, digitalization and the application of ICT in the transport sector is seen as an enabler of new service concepts alongside business opportunities linked to the collection and utilization of real-time data from users, vehicles and other sensor-based technologies. Some meso-level actors also see MaaS as an opportunity to commercialize new vehicle technologies such as autonomous vehicles and electric drivetrains.

With regard to barriers to MaaS developments at the meso level, the literature outlines a range of uncertainties and perceived risks, primarily associated with the new forms of public-private partnerships that MaaS requires,

particularly related to the role of public transit in emerging MaaS ecosystems. These include: uncertainties related to roles and mandates within MaaS ecosystems; uncertainties related to the business case for MaaS, the business model, overall market demand for MaaS services, and willingness-to-pay for and adopt MaaS among different customer segments; perceptions of risks associated with sharing customer data and cannibalization of existing offers following a repositioning of some mobility service providers in the value chain. The future role of public transit in MaaS is further complicated by institutional inertia that keeps employees focused on service delivery rather than innovation, and fears that a transition to MaaS will result in a loss of customers and of control of over brand image (Smith et al., 2019).

Audouin and Finger (2019) argue that choppy beginnings in both Helsinki and Vienna were due to public authorities either "governing by doing" – a fiercely independent approach that forecloses on collaboration – or governing by doing nothing at all. MaaS schemes in both cities progressed further when authorities at different levels adopted a "governing by enabling" approach. Several scholars have argued that the public sector ought to play a much more deliberate role in shaping MaaS, including ensuring equitable outcomes, monitoring data security, ensuring fair market competition, and the possible provision of subsidies to private sector transportation services (Li, 2019; Pangbourne et al., 2020; Wilson & Mason, 2020). As such, existing research has outlined three overarching approaches to organizing the MaaS ecosystem with particular attention given to the role of public sector organizations (Smith et al., 2018):

1. **A market-driven approach** where commercial operators adopt the role as MaaS service provider, enabled by public transit operators and other transport service providers who are willing to allow arms-length third-party sales (thus repositioning themselves further upstream in the value chain). A market-driven approach is thought to be more agile and innovative but limits the influence of public transportation actors on MaaS developments by delegating responsibility for customer interface and service delivery to commercial MaaS operators, who are more exposed to risks and market pressures than other approaches.
2. **A publicly-controlled approach** where public transit operators either adopt the role as MaaS service provider or procure a commercial partner to adopt this role. This approach is motivated by the need to ensure that MaaS delivers positive societal impacts, to guarantee that public transport acts as a 'backbone' to MaaS, and to align potentially divergent interests within the MaaS ecosystem.
3. **A public-private approach** where the public sector adopts the integrator role, allowing public or private actors to adopt the role as MaaS service provider. This approach is thought to lower initial investment costs for MaaS providers as they will not have to develop their own integration platform. The inclusion of a public actor as an integrator is also thought to assist in overcoming conflicts of interests between transport service providers and MaaS providers.

Despite these advances, the appropriate role of public sector organizations like public transit authorities and local/regional governments is hard to generalize and will likely vary across contexts. A comparative study by Hirschhorn et al. (2019) highlights how transportation regimes in different countries have applied very different approaches to an emerging MaaS niche. In Amsterdam, public transit authorities have taken a very "hands-on" approach to the MaaS niche, despite the fact that existing legislation denotes that Dutch public transit authorities take a relatively "hands-off" approach. In Helsinki, a strong centralized public transit regime is heavily involved in the MaaS niche. While Finnish public transit initially viewed MaaS as a threat to their customer base,

it has since learned that high involvement is necessary for customer retention.

Further barriers to MaaS developments at the meso level include a lack of leadership, knowledge and competence within organizations that can play a key role in facilitating and enabling MaaS developments; the absence of digital ticketing and data sharing protocols within public transportation; a reluctance to allow third-party sales within public transit authorities and other established mobility service providers (e.g., car clubs); varying innovation capabilities among different actors; and a lack of knowledge regarding the sustainability impacts of MaaS among key organizations.

6.3 MICRO-LEVEL DYNAMICS

To date, the near consensus goal of MaaS scholarship and advocacy has been to help individuals transition away from the cost burdens of personal vehicles, thus reducing road congestion and carbon dioxide emissions. The website for the MaaS Alliance – a network of European public and private organizations interested in MaaS – states, "The aim of MaaS is to provide an alternative to the use of the private car that may be as convenient, more sustainable, help to reduce congestion and constraints in transport capacity, and can be even cheaper" (MaaS Alliance, 2020). In their analysis of the rhetoric surrounding MaaS, Pangbourne et al., (2020) describe how MaaS offers a set of "interdependent promises" to cities (more efficient and low-carbon roadways), business (new markets in response to changing demands), and to citizens (reduced costs and user-centric). The "user centric" approach espoused within the MaaS discourse is, however, sometimes overlooked in practical applications given the multitude of factors that pose barriers to MaaS developments at the meso level. Notwithstanding, the literature does outline key insights related to micro-level factors (i.e., individuals' attitudes, needs and preferences) that influence MaaS developments.

At the micro level, the existence of unresolved problems related to everyday travel is one key driver. For example, a significant proportion of travelers see car ownership as a large financial burden, and congestion and parking are also perceived as motivations to switch from private car usage to MaaS. Some travelers also appear to be motivated to trial or adopt MaaS because they are curious about the MaaS concept, and interested in the convenience, flexibility, and simplicity that it affords. A further driver in this category is linked to the idea that MaaS can enable modal shifts toward more active and environmentally benign transport modes (e.g., public transport, bicycling and walking) – areas in which individual travelers express increasing awareness and interest.

Existing research has outlined several micro-level barriers to MaaS developments, including: a lack of willingness to learn about, change habits and acquire the necessary competence to utilize new mobility concepts; perceptions among some travelers that MaaS is not a cost-saving alternative; an unwillingness among some travelers to adopt services with monthly subscriptions whereby one must pay in advance; mismatches between service content (cost, included transport modes, administrative routines, etc.) and actual travel needs; a lack of flexibility among some travelers without cars; and perceptions of feeling 'locked in'.

7 MAAS AND THE COVID-19 PANDEMIC

This literature review is being composed during the global COVID-19 pandemic – officially declared a pandemic by the World Health Organization on March 11, 2020. The highly contagious spread of COVID-19 had a dramatic and instantaneous effect on individuals' transportation routines in the Spring of 2020. These changes have

endured for nearly a year and involve a decline in transportation *overall* due to individuals either working from home or losing their jobs, plus the closure (both temporary and permanent) of indoor public spaces around the world that has limited social activities outside the home. Shared transportation modes have experienced an even steeper decline in ridership as individuals that continue to commute to their jobs have transitioned to individualized travel modes like personal vehicle, bicycle, or walking.

As one example, preliminary reporting from Sweden's three largest metropolitan regions reveals precipitous declines in public transit ridership beginning in March 2020. In the regions surrounding Stockholm, Gothenburg, and Malmö, the number of daily public transit trips fell approximately 60, 40, and 50 percent, respectively, relative to the same time period in 2019 (Jenelius & Cebecauer, 2020). Travelers in these cities have been discouraged by the public transit authorities themselves from using shared transportation modes unless absolutely necessary. Consequently, each transit system has experienced swift declines in revenue from ticket sales, especially from monthly and seasonal transit passes (ibid). Pedestrian flows in Stockholm's inner-city have experienced similar sharp declines, while bicycle and automobile flows have remained relatively stable, suggesting that individuals feel less threatened by the pandemic while using individualized forms of travel. This may mean that "post-pandemic" scenario could involve new stresses to roads and bicycle infrastructure if travelers continue to avoid shared transport modes. A similar pattern has emerged in countries around the world, where smartphone location data show a dramatic decline in activity level near transit stops between February and June of 2020 (Tirachini & Cats, 2020). These patterns have also been documented in studies focused on individual countries (for a review of such studies see Gkiotsalitis & Cats, 2020) and in the popular press (Marshall, 2020).

The current challenges to public transit have obvious implications for ongoing MaaS initiatives and the future of MaaS. Public transit has been labeled a "backbone" (Jittrapirom et al., 2018; MaaS Alliance, 2017) and a "centerpiece" (Hensher, 2020) of MaaS, and remains a key stakeholder in all known commercial MaaS operations to date. Given the trepidation expressed by PTAs *prior to* the pandemic and the likely financial strains that PTAs face today and for the foreseeable future, public transit's "backbone" role in MaaS cannot be taken for granted.

There is a the potential, however, for MaaS to reimagine itself in light of these societal changes. Hensher (2020) reflects on possibilities for MaaS in the coming months and years, speculating that the current pause in travel due to increases in work-from-home offers a chance for a "reboot" that discourages a return to personal vehicles. This could be achieved through flexible MaaS offerings that initially rely on individualized modes (e.g., bicycles and car rental) as well as rideshare with a small number of trusted acquaintances (a social bubble). Hensher also emphasizes opportunities to broaden the scope of *services* that MaaS includes, for example retail and food delivery options bundled in a subscription with transportation services. There are also reports of innovative applications of MaaS to resolve transportation shortages related to the pandemic. The state of Israel established a MaaS system to provide efficient transport to its emergency responders and essential workers despite operating on a limited schedule (Ben Dror & Azaria, 2020).

The potential for MaaS a tool for transport resilience has also been underexplored in research and practice. The societal shocks related to the COVID-19 pandemic has revealed that flexible transport options are critical in times of crisis – health related or otherwise. A system that enables travelers to seamlessly transition between available transportation modes despite unplanned systemic interruptions (e.g., infrastructure failures, energy

crisis, cybersecurity attack, natural disasters, etc.) could temper broader societal shocks and allow for a continued sense of normalcy. Public sector agencies can use this rationale to encourage broader participation in MaaS projects and public funding for MaaS initiatives that are well tailored for emergency response.

8 CONCLUSION

This report has synthesized the state-of-knowledge of MaaS as described in peer-reviewed academic literature. While MaaS research has flourished in recent years, it is clear from this review that the particular challenges and contexts relevant to the **Stronger Combined** project remain under-researched. To the extent that MaaS research is focused on specific locations, it is disproportionately focused on urban and urban/suburban locations while rural, small-town, and specifically suburban and peri-urban challenges remain largely ignored. If one objective of MaaS adherents is to encourage a general transition away from personalized vehicles, then it would make sense for R&I activities to focus on the challenges that populations and locations *outside* dense urban transportation networks face. Future R&I programs can investigate not only how rural and suburban travelers could be compelled, for example, to use public transit and carpooling services to access the city center, but also how travelers in these poorly connected places can affordably improve travel options and connectivity *within* these spaces. Alternatively, if most research continues to focus on the apparent "low-hanging fruit" of MaaS in dense urban cores, there is a risk that future MaaS applications will exclude large and rapidly growing segments of metropolitan populations.

A rather consistent finding in the reviewed literature is that while subscribing to MaaS appears to stimulate the use of public transit and non-motorized transit options, households with personal automobiles remain reluctant to abandon them entirely. There are many policy approaches that are not necessarily related to MaaS that can contribute to overcoming this particular challenge. For example, urban development policies that facilitate walkable and transit-oriented neighborhoods, that restrict the supply of parking, installing congestion pricing, and increasing fuel taxes are among many approaches that can be deployed to encourage low-carbon, high-efficiency transportation systems. Future scholarship can more directly probe how MaaS systems intersect with these policy levers. For example, several of the **Stronger Combined** living labs have partnered with local authorities, schools, hospitals and retail establishments to develop "mobility hubs" that co-locate different transportation modes and transportation support services. Academic literature has yet to probe how these strategies overlap, where it has succeeded, and how policy can improve it.

While this review offers a synthesis of literature about the challenges and opportunities of MaaS, it has not integrated research related to business models, IT platforms, data standards, and innovations in supplementary infrastructure that may indeed play a large role in the future of MaaS around the world. Payment and ticketing standards among different transit authorities, for example, can facilitate seamless transfers between transit services based in different regions or between different carriers within the same region. While such standards are under development at this time of this writing, research on this topic did not emerge in our literature review.

This report has synthesized many of the pilots described in academic literature. However, there have been – and continue to be – MaaS pilots that are *not* covered by published academic articles. As such, the published knowledge of MaaS pilots may be unrepresentative of the actual knowledge emerging from public and private sector experiments in MaaS. For instance, a number of pilots that trial MaaS in rural areas for both residents

and tourists have either been conducted or are currently underway in countries such as Finland, Scotland and Sweden. A number of key issues remain unaddressed presently in the emergent MaaS literature. What types of mobility services must be combined in order to attract travelers in these locations? Who does what in the MaaS ecosystem? What are the potential and actual sustainability impacts of MaaS in rural settings? This gap is an obvious shortcoming and ought to be addressed by additional funding that allows for peer-reviewed reporting of MaaS pilot results. Moreover, the deployment of MaaS in non-urban settings such as rural and peri-urban locations may be critical to the fulfilment of sustainability objectives given the typically heavier reliance on privately-owned automobiles in these areas.

Finally, the analysis above reveals that much existing MaaS scholarship comes from a small number of countries and focuses on a similarly small number of locations. Given the complex and highly context-dependent nature of transportation systems, prescribing best practices for a transition toward MaaS and other servitized transport models will require that future scholarship actively includes a wider variety of cases from underexplored national and spatial contexts. Solutions that work well in Finnish cities, for example, may be difficult to transplant to other countries and settings. Thus, future MaaS scholarship ought to actively broaden the contexts in which surveys, pilots, and modelling scenarios take place.

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