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Mobility as a service and socio-territorial inequalities: A systematic literature review

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

Keywords: MaaS, inequalities, transport justice, accessibility, well-being

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1 Introduction

In the twentieth century, mobility solutions were focused on private motor vehicles. Not only did these solutions alter the urban form (De Vos & Witlox, 2013; Lowry & Lowry, 2014), but they became a source of negative externalities, ranging from pollutant emissions (Banister, 2011), exposure to health risks (Tranter, 2010), to social and territorial exclusion (Lucas, 2019; Mackett & Thoreau, 2015). To counteract these undesired effects, smart mobility was introduced at the beginning of the twenty-first

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century (Butler et al., 2021). Following the sharing economy trend (Ganapati & Reddick, 2018), and benefiting from advances in communication technologies, mobility as a service (MaaS) became a promising avenue for more sustainable, inclusive, and efficient mobility. However, despite interest from academia and other urban stakeholders, the practical benefits of MaaS concerning environmental and social challenges remain largely unknown (Arias-Molinares & García-Palomares, 2020).

Current transport theory and practice give a central role to accessibility, both as one of the main aims of mobility planning (Deboosere et al., 2018; Handy et al., 2005), and as a non-material primary good to be taken into consideration from the point of view of justice (Pereira et al., 2017). The ability to easily reach a desired destination has tangible direct and indirect benefits for people's quality of life (Garcia et al., 2018; Lucas & Musso, 2014), and theories of justice indicate that a just system should aim for "the morally proper distribution of benefits and burdens over members of society." (Martens et al., 2019, p. 13). Together with the land-use system, access to transportation is crucial to guarantee social inclusion, as it offers equal access to opportunities such as employment, essential services, and recreational facilities (Butler et al., 2021). However, access to opportunities is unfairly distributed within many territories and societies (Grengs, 2012; Pereira et al., 2017) indicating that transportation systems are a source of unfairness (Gössling, 2016). In this context, we hypothesize that although MaaS was intended to be an efficient, sustainable, and convenient solution, its practice suggests that it could generate socio-territorial inequalities (STIs) if not adequately integrated.

The first well-known definition of MaaS is given in Hietanen (2014, p. 2), who describes it as a *"mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider."* It is a recent concept, still evolving, which lacks a solid understanding (Arias-Molinares & García-Palomares, 2020). Many authors have sought to address this gap by evaluating the state of the art. Several reviews have explored MaaS from different points of view. These include technological advancements (Palmer et al., 2018; Silva et al., 2020); business models (Durand et al., 2018; Ribas et al., 2020); theoretical conceptualizations (Arias-Molinares & García-Palomares, 2020; Giesecke et al., 2016); travel behavior impacts (Kamargianni et al., 2016); the implications of local policy and governance (Santos & Nikolaev, 2021; Slavulj et al., 2020); and end-users perceptions (Jittrapirom et al., 2017). Other reviews have examined the impacts of MaaS on environmental sustainability (Butler et al., 2020b; Liyanage et al., 2019; Storme et al., 2021) and social conditions (Butler et al., 2020a; Gompf et al., 2020).

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

This review is structured into five sections, including this introduction. Section 2 presents the concept, along with its expected benefits and burdens, and Section 2.2 discusses inequality from a transportation point of view. Section 3 presents the methodology. Section 4 presents the main findings, and in Section 5 we discuss MaaS schemes and their association with STIs in depth.

2 Conceptual background

Although its practical benefits and future consequences are still largely unknown, mobility as a service (MaaS) has been growing worldwide since its first official appearance in 2014, in Finland. It promised a one-size-fits-all solution that could revolutionize the future of urban transport (Hietanen, 2014). According to Heikkilä (2014, p. 8), MaaS is *"a system in which a comprehensive range of mobility services are provided to customers by mobility operators."* In other words, it is a service that, through a shared digital channel, enables users to plan, book, and pay for multiple types of mobility (Smith & Hensher, 2020). An alternative definition is given by Durand et al. (2018, p. 3), where it is envisaged as *"a concept that integrates existing and new mobility services into one single digital platform, providing customized door-to-door transport and offering personalized trip planning and payment options."* The latter definition stresses the requirement to satisfy the user's needs, and the integration of multiple modes within a single interface, normally requiring the use of a portable device (smartphone) connected to the internet. As the term suggests, the main objective of MaaS is to allow individuals to access relevant opportunities without the need to own a means of transport, thereby transforming mobility into a service that can be used whenever needed.

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

2.1 MaaS: Structure and levels of integration

MaaS systems rely on the integration and co-operation of at least five key players: (i) transport users, i.e., customers who hire the mobility service to access a particular destination, (ii) transport operators (public and/or private) who supply the mobility service by providing their vehicle (with or without a driver), (iii) mobility brokers (also designated as MaaS providers), who sell the mobility service to users by providing a platform that connects and organizes interactions between them, (iv) data and technology providers, who operate telecommunications systems and supply technological solutions, and (v) policymakers, i.e., public authorities who are responsible for enforcing regulations and protecting societal goals (United Nations, 2020; Wong et al., 2020; Zhang & Zhang, 2021). Conceptually, customers (users) interact with suppliers (operators) via a mediator (the mobility broker). This interaction relies on existing channels (data/tech providers), while all players are subject to governmental agencies (policymakers) (Figure 1).

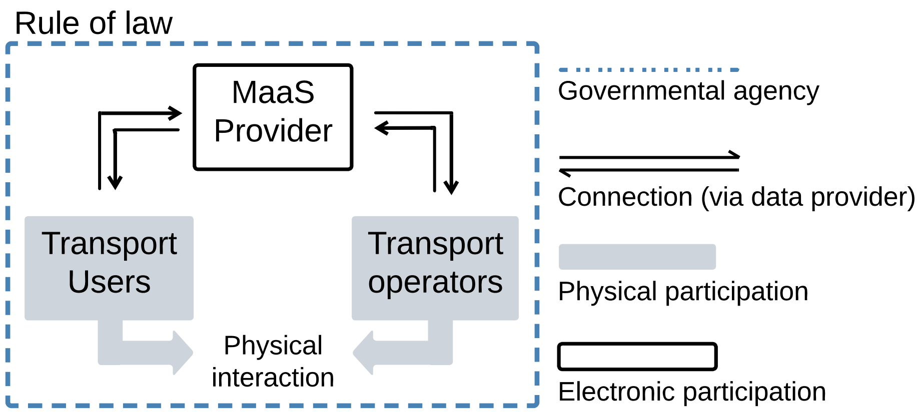

Figure 1. Simplified MaaS scheme, showing the five key players

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

2.1.1 MaaS integration

Several authors have defined schema to characterize transportation systems in terms of the level of MaaS integration (Table 1). For example, Sochor et al. (2018) and Ho et al. (2021) identify four incremental levels: the integration of information; booking and payments; bundled services; and societal values. The latter authors note that the main limitation in current MaaS systems relates to the highest level—the integration of societal goals. Alternatively, Lyons et al. (2019) interpret integration from the perspective of the cognitive effort of users. They identify five levels: no integration; the integration of operational and multimodal information; the integration of limited modes; the integration of all modes in certain circumstances; and the integration of all modes in all circumstances. Finally, Bandeira et al. (2021) state that current analyses of MaaS integration levels neglect important dimensions such as geographic coverage and sustainability. They propose six categories: environmental policy; social cohesion; personalization; IT integration; multimodality; and geographic area, rating them from 0 to 5 to provide a final score based on the sum of each category.

Table 1. Current characterizations of MaaS integration levels

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

The above approaches exemplify attempts to characterize MaaS integration but are not free of limitations. For example, it is not immediately obvious what being a level 4 MaaS system means, beyond the number. Furthermore, characterizations are assumed to be incremental; for instance, a system that is classified as level 4 is assumed to encompass the benefits of all the lower levels. However, this may not be true, as a system may meet level 2 requirements, but not those of level 1. This point is illustrated by ride-hailing companies (also known as transportation network companies) that allow single-trip planning and payment, but do not offer multimodal integration. Although the approach presented by Bandeira et al. (2021) introduces more dimensions, it gives the same weight to all categories, which can be misleading if we want to assess the system from a sustainability or equity perspective. Moreover, the final scores lack meaning and only allow a numerical comparison of levels. These observations highlight that the literature lacks a descriptive system that makes it possible to rank and compare different MaaS systems, using societal impact as a cornerstone. Such a methodology would allow practitioners and researchers to characterize, identify, and properly assess different MaaS systems.

2.1.2 Benefits and burdens

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

However, there is little empirical evidence of the benefits of MaaS. Reported outcomes include a reduction in per capita vehicle kilometers traveled, increased trip awareness and planning, a potential shift from private cars to active modes (Smith & Hensher, 2020), reduced private vehicle ownership and parking demand, improved social equity (Butler et al., 2021), and a reduction in the impact of home and work locations on transport costs (Wong et al., 2020). MaaS is also reported to potentially improve service quality, supply better data and mobility information (for both users and brokers), and increase price competition (Arias-Molinares & García-Palomares, 2020). It has, in a few, limited cases, been shown to make it easier for citizens to access and utilize complementary mobility services (Sochor et al., 2016).

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

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

2.2 Transport inequality

MaaS may have a negative impact on social and territorial equity. It is well-known that transport is a source of inequity, associated with social and territorial exclusion. Transport inequality is understood as differential transport conditions for distinct groups (Hidayati et al., 2021), while exclusion is a state where an individual or group is unable to participate in activities that are considered normal in a specific civil society (Pritchard et al., 2014). While there is a clear association between transport inequality and poverty, it is repeatedly associated with many other social issues (Gössling, 2016). A clear example of transport inequality relates to the conditions that users of private and PT systems are subject to (Springs, 2007). Simply put, lower-income households have less access to both private vehicles and central locations, as prohibitive costs force them to reside in the most poorly served suburbs (Fedorowicz et al., 2020). This creates a precarious situation for families that must rely on slower modes (compared to private vehicles) and endure longer commuting times in less comfortable conditions.

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

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

The first component – distributive principles – relates to several theories of justice that discuss the fair (or reasonable, or just) allocation of benefits and burdens in society. All plausible theories of distributive justice (utilitarianism, libertarianism, egalitarianism, justice as fairness, sufficientarianism, etc.), share the general idea of equality; however, this does not mean that they all agree on what benefits should be equally distributed (Dworkin, 1977; Kymlicka, 2002). While one defends the right to equal income and wealth, another defends the equal right over one's labor and property. Nevertheless, equality is a fundamental concept that is used to support how individuals in a social organization should be treated. Therefore, the debate about justice theories and distributive principles is not founded on the question of the acceptability of equality as a fundamental value (since all theories agree on this), but rather on how to interpret it, or what benefit(s) should be equally distributed.

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

(1) **Resources (R)** relate to individual or household attributes (either owned or attributed by the environment). For example, owning a car; the availability of bicycle infrastructure; the availability of an unpolluted environment.
(2) **Opportunities and risks (O)** relate to the implications of holding certain resources, as it is possible to hold a resource but lack opportunities (e.g., a car owner who is banned from driving), while other conditions may pose a risk (cyclists who use unsafe infrastructure).
(3) **Outcomes (O)** are objectively measurable benefits or burdens, (e.g., the number of trips, the time spent, expenses, and the number of car crashes).
(4) **Wellbeing (W)** refers to people's subjective perception of their situation, which results from the interplay of resources, risks and opportunities, outcomes, and context.

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

3 Systematic review methodology

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

Our study focused on real-world applications (RWA) of MaaS. Scopus and ScienceDirect metasearch engines were used to identify peer-reviewed articles or conference papers, while book chapters and the gray literature were not considered. The method is presented in Figure 2. The keywords used were “MaaS” OR “Mobility as a Service” OR “Shared mobility” AND “Case study”; “Experiment,” “Pilot”; “Trial”; “Program”; “Impact”; and “Application” in the domains of Social Sciences, Engineering, Environmental Sciences, Computer Sciences, Decision Sciences, Econometrics, and Finance. Merging results from both search engines resulted in 2009 distinct papers. Next, we filtered the dataset to identify papers that assessed transport inequality. In this step, we used the Rayyan software package (Ouzzani et al., 2016) to enter 10 relevant keywords ((in)equity, (in)equality, (in)justice, (in)exclusion, socially, disadvantaged). This resulted in 146 distinct papers that had at least one of these keywords in the title, abstract, or as a keyword.

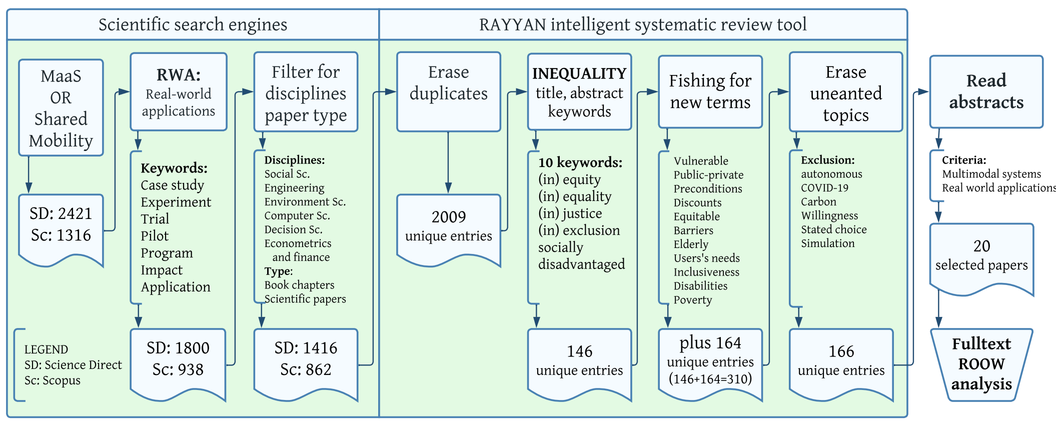

Figure 2. Flowchart showing the steps taken in the systematic literature review

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

The findings reported in the selected papers were then evaluated in terms of how they reflected inequalities associated with a MaaS scheme. We adopted the Resources, Opportunities, Outcomes, and Wellbeing (ROOW) approach, (Section 2.2) given that it provides an analytical framework to conduct a systematic equity analysis. Furthermore, it is one of the first approaches designed exclusively to measure equity in the transportation area. This approach focuses on the individual/user and not on other stakeholders, which could be a limitation; however, as we aim to identify STIs, it fulfills our requirements. Equity measurement in transport is still in the early stages of development, and hence, there are no defined indicators to address it as there are in other fields such as housing or health.

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

The reported RWA case studies illustrated the four ROOW classes for each MaaS scheme. We searched for textual evidence associated with the core elements of each class (Table 2). Beginning with R, we searched for (direct or indirect) argumentative evidence of conditions that might affect access to the MaaS system and classified them into six broad categories: *budget, location, readiness, savviness, vehicle, and infrastructure.* For instance, Resources were associated with a *budget* if the system had a minimum entry price. They were associated with *savviness* if they required an understanding of complex technology, and they were linked with *infrastructure* if access was hindered (by communication difficulties, difficulty boarding a vehicle, mode competition, etc.). We applied the same logic to the other three categories. Turning to Op, we classified opportunities into three categories based on *costs, time, or equity*. For instance, systems could have an observable effect on total transport expenditure (*costs)*, the amount of time spent in transit (*time*), or differential access to opportunities (*equity*). Regarding *Ot*, benefits were identified if a paper reported changes in travel patterns resulting from MaaS usage. These changes were grouped into four categories (*distance/time, total trips, mode change, and preferences*) and reported either numerically (e.g., 20% increment in trip-chaining) or descriptively (e.g., a general reduction in kilometers traveled by car). Finally, for W, we searched for reports of travelers' opinions, perceptions, or any descriptions of satisfaction levels (e.g., the dropout percentage, opinions, and preferences).

Table 2. Factors identified per class

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

4 Case studies: Description and assessment of benefits/burdens

Our findings indicate that only a few studies have investigated the impact of MaaS on STIs. While the majority of the MaaS literature cites potential concerns regarding increased inequality, we focused exclusively on RWA studies. Table 3 lists the 20 papers identified for review and gives a short description of each case study's characteristics. The description encompasses sociodemographic and methodological aspects, as some studies examined the same sample population from different perspectives.

Table 3. Characterization of MaaS trials in chronological order of publication

Reference	Case study	Sample	MaaS system	Assessment method
Karlsson et al., 2016 Strömberg et al. 2018 Sochor et al., 2016	Gothenburg, Sweden 580k pop; $51,620 GDP/capita Modal share: PT 29%, auto 48%, bike 14%, walk 9%	195 people (173 adults): Mean age 38 91% daily app users 88% hold driving license 46% car owners Six-month field test	UbiGo (smartphone app) Include PT, taxi, car and bike sharing, rental cars Bundles from €135 or $185 per month	Questionnaires (pre, during and post-trial) + interviews + travel diaries
Smith et al., 2018	Sweden/Finland, no specific city	31 interviews with 34 key stakeholders from public, private and research sectors	Multiple systems: IRIMS framework	Semi-structured interviews
Chang et al., 2019	Taipei, Taiwan 2.8mi pop; 9,918/km^2; $33,000 Modal share: PT 39%, auto 39%, active 10% taxi 12%	1000 registered users 40km Taipei-Yilan corridor	UMAJI (full multi-modal MaaS environment) Bundles $43/month Value services: gift, restaurants, accommodation.	Usage records during an open trial (2017 and 2018)
	Kaosiung, Taiwan 2.7mi pop; 7100/km^2; $26,600 Modal share: PT 39%, auto 39%, active 10%, taxi 12%	15,492 packages sold 3-month operation targeted at students aged 17–22 and white-collar commuters	MenGo (smartphone app.) Including city and intercity buses, MRT, light rail, ferries, shared bikes. 4-month service packages	Usage records during an open trial (2018)
Kanuri et al., 2019	Bangalore, India 10mi pop; 11000/km^2; $3300 Modal share: PT 29%, auto 10%, bike 5%, walk 29%	93 regular users of integrated modes; 2 feeder and 1 parking services were piloted; At selected metro stations	STAMP (Station Access and Mobility program): Metro, parking, and feeder lines. App information systems available	Trial followed by an user survey.
Barbour et al., 2020	Florida, USA (3 cities) 940k pop; $44.300 GDP/capita Modal share: PT 1,4%, auto 80% bike 0,7%, walk 1.43%	675 respondents	The CycleHop (incomplete MaaS system)	Questionnaire on travel behavior (ride-sourcing users)
Böcker et al., 2020	Oslo, Norway 640k pop; $87.000 GDP/capita Modal share: PT 39%, auto 36%, bike 7%, walk 18%	4.4 million trips in the bike sharing system	CityBike (PT and bike integration)	Assessed the effects of PT connectivity on total bike sharing frequency

Reference	Case study	Sample	MaaS system	Assessment method
Karlsson et al., 2020	Gothenburg, Sweden 580k pop; $51,620 GDP/capita Modal share: PT 29%, auto 48%, bike 14%, walk 9%	83 households participated in a six-month trial	UbiGo (smartphone app.) Includes PT, taxi, car and bike sharing, rental cars in bundles, costing €135 to185 per month	Questionnaires + individual interviews
	Västra Götaland, Sweden 1.7 mi pop; $47.280 GDP/capita Modal share: PT 21%, auto 52%, bike14%, walk 12%	19 participants, potential investment's firms	UbiGo (smartphone app.) Includes PT, taxi, car and bike sharing, rental cars in bundles costing €135 to185 per month	Individual meetings + semi-structured interviews with potential bidders
	Malmö/Lund, Sweden 350k pop; $55.340 GDP/capita Modal share: PT 15%, auto 58%, bike 16%, walk 11%	8 participants. Residents 100% car owners	EC2B (housing based MaaS service) Includes PT, shared bikes and cars, car rental, and delivery	Individual interviews
	Finland (whole) 5.5mi pop; $49.041 GDP/capita Modal share: PT 30%, auto 39%, bike 8%, walk 21%	9 stakeholders 3 mixed groups of firms and government	Multiple platforms (Whim, Tuup, Sonnera Reisu and Kätävä, and more)	Interviews with stakeholders + MaaS-related policy documents
Eckhard et al., 2020	Finland 2 trials in 3 rural areas: 1.Porvoo 50k pop. 2.Kuru 3k pop. 3.Vamala 16k pop Finnish GDP/capita: $49.041	1) 69 users (363 trips; 281 routes; 15 respondents 2) 9,442 trips; 5,727 trips	Kyläkyyti (demand-responsive) Includes shared taxi, and minibus; APP and CALL center; €3 to €5 per trip	End-user surveys and data provided by service providers + workshops, surveys, interviews, data collection.
Hesselgren et al., 2020; Zhao et al., 2020	Stockholm, Sweden 1.6mi pop; 3,858/km^2; 72,803 Modal share: PT 32%, auto 46%, bike 7%, walk 15%	15,000 participants 70 buildings Limited to the company area	Corporate MaaS Pilot: Includes taxis, shuttle and commuter buses, 40 shared e-bikes (no active modes)	Individual semi-structured interviews with users Travel logbook
Singh, 2020	Kochi, India 2.1mi pop; 7100/km^2; $3100 Modal share: PT 42%, auto 36%, bike 3%, walk 12%, alt. 7%	Open pilot (Dec 17–May 18) 9 key stakeholders invited (metro + 6 bus operators; rickshaw drivers; taxi drivers)	Kochi One (app+smartcard) Includes metro, buses, rickshaw, boats, and bikes	Stakeholder roundtable
Storme et al., 2020	Ghent, Belgium 260k pop; $47.611 GDP/capita Modal share: PT 20%, auto 27%, bike 30%, walk 18%.	100 participants from Ghent University. All were car owners, and smartphone + data plan owners 2.5 months in 2017	MaaS pilot (own app) Includes bike sharing and rental, car-sharing and rental, taxi, PT	Usage records during trial

Reference	Case study	Sample	MaaS system	Assessment method
Abdelwahab et al,. 2021	Toronto, Canada 2.7mi pop; $43.100 GDP/capita	16 planning districts 625 Traffic analysis zones Focus on under-resourced areas	No official name	Measured generalized cost of travel and accessibility levels Access profile analysis
Bauchinger et al., 2021	Graz, Austria 500k pop; 1228/km^2; $40000 Modal share: PT 20%, auto 42%, bike 19%, walk 19%	87 active users (registered)	REGIOtim e-carsharing + Charging Cycling + (Micro-Public transport	Analysis of potential locations for tim nodes; Pilot users survey;
Hensher et al., 2021	Sydney, Australia 5.4mi pop; $84,700 GDP/capita Modal share: PT 25%, auto 59%, bike 3%, walk 4%	92 participants: 100% iPhone users 100% IAG workers 2-year trial	Tripi (MaaS platform) Includes PT, rideshare, car share and car rental. PAYG/bundles from $25 to $125 per month	Observe the dynamic of monthly-bundle adoption and PAYG in distinct scenarios
Ho et al., 2021	Sydney, Australia 5.4mi pop; $84,700 GDP/capita Modal share: PT 25%, auto 59% bike 3%, walk 4%	Five-month trial IAG Employees 150 potential participants 93 final participants	Tripi (MaaS platform) Includes PT, rideshare, car share and car rental. PAYG/bundles from $25 to $125 per month	Revealed preferences, pre- and post-trial surveys and interviews, Mixed logit modeling
Hult et al., 2021	Pilots in rural areas in Sweden: 1. Skattungbyn (pop 293) 2. Södra Årefjällen 3. Torhamn (pop 421) 4. Broddetorp, Timmersdala Lundsbrun (pop 2500) 5. Broddetorp (pop 822)	1. Since Nov. 2018 2. Since Feb. 2020 3. Mar. 2018 to Apr. 2018 4. Since Oct. 2020 5. Aug. 2013 to Sep. 2018 27 interviews	1. DalMaaS: ridesharing + special transport 2. FjällMaaS: PT, bus service, delivery, and ridesharing 3. Hämta: Ridesharing + PT 4. KomILand: Car and bike sharing, and taxi 5. Mobil-samåkning: Ridesharing	Participatory observation and interviews with actors in five pilots
Jiao & Wang, 2021	New York City, USA 19mi pop; $75.131 GDP/capita Modal share: PT 33%, auto 55%, bike 1%, walk 6%	Trip data from Uber, Lyft, Citibike and taxis	No official name Includes bikeshare, ride hailing, and taxis	Trip diary records from trial users

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

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

The analysis revealed significant differences between trials concerning the context and the development stage. Due to the complexity of deploying a multimodal digital transport pilot, most cases were based on small samples, which jeopardized generalizing their results, as acknowledged by several authors (Barbour et al., 2020; Bauchinger et al., 2020; Hensher et al., 2021; Ho et al., 2021; Hult et al., 2021; Kanuri et al., 2019; Storme et al., 2020) highlighting the importance of conducting bigger pilots, some (Chang et al., 2019; Hesselgren et al., 2020; Jiao & Wang, 2021) used significantly bigger samples and treated participants as active system users. Finally, a few trials (Karlsson et al., 2020; Singh, 2020; Smith et al., 2018) focused on the operator's point of view rather than users (and hence used a smaller sample).

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

In this section, we evaluate the impacts identified in MaaS trials with respect to the four classes of benefits/burdens (ROOW). Reported results were classified as a function of resources relevancy for adoption, opportunities, outcomes, and whether there was a positive or negative effect on wellbeing. It should be noted that some papers reported no results regarding one or more of these items. Table 4 presents the results of our evaluation and lists the main conclusions for each of the four classes. It is interesting to note that even though some papers assessed the same trial, the results of the ROOW analysis offer different perspectives.

Table 4. Synthesis of the ROOW analysis for the selected papers.

Paper	Resources	Opportunities	Outcomes	Wellbeing
Karlsson et al., 2016	(Coverage) Distance to car-sharing (Budget) Some did not join due to cost/benefit ratio	-	(Modal change) Less private car use; More alternative modes use; Overestimated importance of car	(Positive) Participants wanted to continue as customers (97%); Less positive towards private cars
Sochor et al., 2016	(Budget) Price was a significant variable for system adoption (Coverage) Distance to car sharing sites (Savviness) Familiarity with the MaaS app and systems was a barrier	-	(Total trips) Overall reduction in private car trips (Modal change) Increased use of carsharing and express bus; Increased trip chaining; 20% changed routes and destinations	(Positive) 75% were satisfied with the changes; Users are less positive toward private cars 23%; More positive toward carsharing 61%, PT 52% bikesharing 42%; Easy to pay and to track of costs
Smith et al., 2018	(Coverage) Proximity to stations (Infrastructure) Service competitiveness needs high demand (economies of scale) (Vehicle) Access to cars	-	(Distance) Increased short trips; Longer planning times (Modal change) Access to more modes (diverse modal split); Adoption of healthier behavior (Preferences) Frequent PT user affected by bundle choices	(Positive) 93% satisfied with the system; 69% more satisfied with travel after trial; 79% wanted to continue to use the system

Paper	Resources	Opportunities	Outcomes	Wellbeing
Chang et al., 2019	(Budget) Limited by cost (bundle price)	-	(Modal change) Negligible shifts; 58,800 trips per month shifted from cars to greener modes (Total trips) More trips by users	(Positive) 94% of users continued after the end of the 3-month trial
Kanuri et al., 2019	(Budget) Tariff options ($/km) (Infrastructure) Limited to metro feeder micro mobility	Equity) Children and the elderly gained mobility (Time) Limited commuting time options (to work, from home)	(Modal change) Induced a 43% shift from private vehicles and 48% from PT for first and last miles segments.	(Positive) Good impact on time-savings perceptions (Negative) Low spatial coverage negatively affected perception of users
Barbour et al., 2020	(Budget) User Income (Vehicle) Car ownership (Savviness) Openess to new modes (Coverage) Living closer to activities	(Time) Time gains due to no parking	-	-
Böcker et al., 2020	(Coverage) Proximity to dense areas; limited coverage (Infrastructure) Uphill bike lanes (Readiness) Temporal limitations	(Equity) Poor service for the elderly and women; few gains outside central areas	-	-
Hesselgren et al., 2020	Savviness) App learning curve (Readiness) Time limited services (Infrastructure) Time and capacity limited services	(Time) Time gains due to no parking	(Modal change) Perceived change from walking to shuttle bus; ⅔ of employees who used to commute by car continued to do so; Increase in ride matching	(Positive) Mostly appreciated by employees (Negative) Problems with connections and battery life caused frustration
Karlsson et al., 2020	(Coverage) Parking availability (Savviness) Steep learning curve (Budget) Service costs compared to current costs; Regular charging	(Costs) Minimized travel costs	(Preferences) Observed dropouts due to old habits	-
Storme et. Al,. 2020	(Vehicle) MaaS could be seen as a complimentary service for private car users (Savviness) App design and integration (e. g. trip planner) was a barrier	(Equity) Children and the elderly became more mobile	(Modal change) Cars less used for commuting; Taxis and car-rental were unattractive; Own car is attractive if no sharing system is close by (Total trips) Higher trip frequency	(Positive) Bike is considered pleasant, convenient, and environmentally friendly for short trips (Negative) MaaS is stressful if not well organized

Paper	Resources	Opportunities	Outcomes	Wellbeing
Eckhardt et al., 2020	(Vehicle) Difficult to board vehicles; competition with private cars (Budget) Affordability (Infrastructure) Dependent on smartcard interoperability (Savviness) Digital illiteracy; lack of service awareness	(Costs) Cut in travel cost (Equity) Accessibility gains for rural areas	(Total trips) Less immobility (26%); Increased number of trips (Modal change) Increased modal shift; Reduced emissions (Distance) Reduction of 12.6% in km driven	(Positive) 73% preferred DRT over schedules + routes; Users extremely satisfied with service availability and transport arrival (from APP) (Negative) Dissatisfied with waiting time (by phone)
Singh, 2020	(Budget) Minimum tariff options (Savviness) Learning curve is barrier (Coverage) Spatial constraints	(Costs) Minimized travel costs	(Modal change) High rickshaw usage rates	(Positive) Users felt the system was reliable
Zhao et al., 2020	(Savviness) Lack of info update; lack of service awareness (Budget) Limited incentives (Readiness) Time inflexibility; reliability of real time information	(Time) Easier to parking (Equity) Little access to opportunities outside the company	(Modal change) 21% of respondents claimed they may shift from private car use to CMaaS	(Positive) Satisfaction rate 75% (Negative) Users felt the lack of a trip planning function was a drawback
Abdelwahab et. al., 2021	(Budget) Ride haling cost per hour (Vehicle) Competition between ride haling and transit	(Costs) Minimized travel costs/time; fewer fares (Time) Distances to nearest stations	-	-
Bauchinger et al., 2021	(Coverage) Distance to terminals (Budget) Affordability (Savviness) Age (Infrastructure) Internet coverage	-	(Modal change) 65% of members replaced cars (Preference) Pre-registration was a barrier for first-time users	-
Hensher et al., 2021	(Savviness) Little knowledge about MaaS or trip planning technology (Budget) Limited transport budget; people chose bundles by price (Coverage) All participants were located close to PT	-	(Distance) Lesser car km/month (Total trips) affected usage level (Preferences) Male participants and households with more driving licenses preferred PAYG over bundle	(Positive) All participants are very open to the idea of MaaS schemes
Ho et al., 2021	(Infrastructure) Not customizable (Budget) Costs (Vehicle) Bundle adoption not affected by owning a car	(Equity) Children and elderly became more mobile	(Modal change) Small savings already impact MaaS adoption (Preferences) Will to be more sustainable is an incentive	(Positive) Cost feedback seen as a very positive feature by users

Paper	Resources	Opportunities	Outcomes	Wellbeing
Hult et al., 2021	(Infrastructure) High dependency on tech providers, difficult to deploy innovation in rural areas (Savviness) Uncustomed solutions	(Equity) Risk of increased spatial injustice if PTAs only support communities with strong civic organizations.	(Preferences) Unsuccessful in attracting users for a long period; Solutions should be place-based and not one-size-fits-all	(Negative) Residents/tourists demand innovative, smart, climate-friendly options. (Negative) Users require direct participation
Jiao & Wang, 2021	(Budget) High cost of on-demand ride services (ODRS) (Savviness) Lack of info about ODRS (Coverage) Limited territory coverage	(Equity) Better mobility for challenged people (Cost) Minimized generalized travel costs	(Distance) On-demand service rides are shorter than trips made by car or transit	-

4.2 Results summary according to the ROOW approach

A summary for each focal variable is presented as follows:

4.2.1 Resources

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

I. *Budget* (cited in 15/20 papers): The impact of the service on the end user's budget, which determines whether an individual or family will be able to afford the provided service (e.g., price-based bundles, minimum entry costs).
II. *Savviness* (cited in 13/20 papers): How easy or difficult it is for potential users to understand, interact with, and benefit from the technological solutions that support service usage (e.g., a lack of updated info, app learning curve, awareness of existing systems).
III. *Coverage* (cited in 10/20 papers): Spatial availability, related to the distance between the origin/destination and the system's entry point (e.g., systems with limited geographical coverage, and other proximity challenges).
IV. *Infrastructure* (cited in 8/20 papers): The physical characteristics of the system provided to users (e.g., mobile data availability, tech interoperability, limited capacity).
V. *Vehicle* (cited in 6/20 papers): Limitations imposed by vehicle-based conditions either from the user's or the operator's point of view (e.g., car ownership, difficulty in boarding vehicles, competition between transport modes).
VI. *Readiness* (cited in 3/20 papers): System and users' temporal availability or synchronicity (e.g., time-limited services, schedule reliability).

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

4.2.2 Opportunities

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

I. *Time* gains, in terms of commuting time, parking time, and shorter distances (Abdelwahab et al., 2021; Barbour et al., 2020; Hesselgren et al., 2020; Kanuri et al., 2019; Zhao et al., 2020).
II. *Cost*, in most cases (Abdelwahab et al., 2021; Eckhardt et al., 2020; Karlsson et al., 2020; Singh, 2020) costs were discussed in generic terms. Only one paper presented a detailed cost comparison (Jiao & Wang, 2021).
III. *Inclusion* understood as better accessibility for mobility-challenged groups (such as the elderly and children) due to MaaS usage was mentioned in several papers (Böcker et al., 2020; Eckhardt et al., 2020; Ho et al., 2021; Jiao & Wang, 2021; Kanuri et al., 2019; Storme et al., 2020; Zhao et al., 2020).

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

4.2.3 Outcomes

Reported outcomes could be classified into the following four categories:

I. Modal change (cited in 13/20 papers), relates to decisions taken by MaaS-system users to replace one mode by another. Our analysis indicates increased usage of several modes (a more diverse modal split) (Eckhardt et al., 2020; Karlsson et al., 2020; Sochor et al., 2016; Strömberg et al., 2018), competition between MaaS systems and PT (Kanuri et al., 2019; Smith et al., 2018), shifts from cars to other modes (Bauchinger et al., 2021; Chang et al., 2019; Kanuri et al., 2019; Zhang & Zhang, 2021; Zhao et al., 2020), and cases where car users resisted change (Hesselgren et al., 2020)
II. Total trips (cited in 5/20 papers), refers to a change in the number of trips undertaken by participants. Such changes were either observed as a simple increment in the total number of trips (Chang et al., 2019; Eckhardt et al., 2020; Hensher et al., 2021; Storme et al., 2020), or as improved mobility. Other papers observed changes (notably, a decrease) in the total number of trips made by private car (Sochor et al., 2016).
III. Distance (cited in 4/20 papers), refers to the observed change in trip distance due to MaaS adoption. Results indicate that on-demand service rides are shorter than trips made by car or transit (Jiao & Wang, 2021), that there is a reduction in km driven per month (Eckhardt et al., 2020; Hensher et al., 2021), and that more short trips are made (Strömberg et al., 2018).
IV. Preference refers to behavioral change. This outcome encompasses the direct effects of MaaS adoption on participants' behaviors, excluding modal, distance, or frequency changes. It indicates difficulties in retaining MaaS users after the trial period (Hult et al., 2021), or its effects on users' values and habits (Ho et al., 2021; Karlsson et al., 2020).

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

4.2.4 Wellbeing

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

I. *Positive feedback*: In general this was reported in terms of: General satisfaction (Chang et al., 2019; Eckhardt et al., 2020; Hensher et al., 2021; Hesselgren et al., 2020; Singh, 2020; Sochor et al., 2016; Strömberg et al., 2018; Zhao et al., 2020), savings promoted by the system (Ho et al., 2021), a less positive attitude towards cars (Karlsson et al., 2016; Sochor et al., 2016), or a more positive attitude to alternative modes (Eckhardt et al., 2020; Sochor et al., 2016)
II. *Negative feedback*: Users were unhappy with limited coverage (Kanuri et al., 2019), technical shortcomings such as a lack of planning apps, or e-bikes with flat batteries (Hesselgren et al., 2020; Hult et al., 2021; Zhao et al., 2020), and waiting times (Eckhardt et al., 2020).

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

5 Inequality and justice

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

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

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

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

6 Discussion and conclusions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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