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Full Length Article

# MaaS for the masses: Potential transit accessibility gains and required policies under Mobility-as-a-Service

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ABSTRACT

Transit accessibility, the conditions and distance under which people have access to transit services, is one of the key indicators to assess the performance of cities' transit systems. The more people can access the transit system, the better its performance in terms of social equity (e.g., more equal access to jobs, education, and other opportunities). To inform policymakers and support decision-making, it is crucial to measure potential transit accessibility changes of transport investments. Due to the paucity of available data, however, calculating and monitoring transit accessibility is a difficult task. Anchored in SDG 11 for more 'Sustainable Cities and Communities', the UN has thus proposed a simplified, globally applicable indicator for the performance of cities' transit systems (SDG 11.2.1) that measures the share of the population living in a walking distance of 500 m to the transit system. Building on this definition and leveraging open data sources, we analyze potential transit accessibility gains under Mobility-as-a-Service (MaaS) in Metro Manila, Philippines. We show that the integration of paratransit (i.e., jeepneys) into the transit network could almost triple access to transit from 23.9 % to 65.0 %. The integration of micro-mobility (i.e., e-scooter and bicycles) as a feeder mode could further increase this share significantly (to 97.9 % and 99.9 %, respectively). We outline and discuss evidence-based policy recommendations to exploit this potential and foster a sustainable development under MaaS. Finally, we conclude with a research agenda for micro-mobility and MaaS in developing countries, a topic which has been widely overlooked in the scientific literature so far.

## 1. Introduction

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

This instantly relates to the Global North, where the private car has become the most dominant transport mode after decades of auto-centric developments. However, while it is claimed that many developed countries have already surpassed 'peak car' (Metz, 2013), the fastest transport-related GHG emissions growth is observed in the Global South (i.e., in Eastern Asia, Southern

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Asia, Southeast Asia, and Africa) (Lamb et al., 2021). Global megatrends such as population growth, urbanization, and high motorization rates are likely to propel such growth in the future. As many countries of the Global South are already facing the environmental consequences of global warming and climate change (i.e., sea-level rise, extreme weather events, droughts, wildfires, and so forth), countermeasures and immediate actions are needed (Schleussner et al., 2018).

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

A prominent reason that inhibits the use of public transport in developing cities, however, is the lack of access to transport infrastructure and services. This does not only impair sustainable mobility behavior, but also exacerbates social exclusion and inequalities (Preston and Rajé, 2007). Transport-related social exclusion could result in lower involvement in social activities, lower opportunities for social advancement, involuntary unemployment, and many other social and economic disadvantages (Lucas, 2012).

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

In this research, we discuss a potential solution for developing cities to address this deficit: the widespread introduction of Mobility-as-a-Service (MaaS) (Hasselwander and Bigotte, 2023). MaaS is a recent phenomenon and frequently praised as an alternative to the private car. It aims to provide seamless, intermodal travel options by integrating public and private transport modes on a single platform accessible on demand (see Arias-Molinares and García-Palomares, 2020b and Jittrapirom et al., 2017 for comprehensive presentations on this topic). First studies and field trials, indeed, find that MaaS could be a promising pathway towards more sustainable mobility futures in both developed (e.g., Becker et al., 2020; Sochor et al., 2016) and developing context (e.g., Hasselwander et al., 2022b; Singh, 2020). While MaaS would actually not increase the value of the SDG 11.2.1 indicator (as per UN definition[1]), the integration of feeder modes, however, could indeed improve access to the transit network. In this research, we specifically focus on the possible integration[2] of informal and semi-formal transport services (paratransit) and micro-mobility.

Using an approach that leverages open data sources and that is easily replicable to different contexts (Nieland et al., forthcoming), we use the case of Metro Manila to calculate potential transit accessibility gains under MaaS. Metro Manila is a characteristic megacity in the Global South in which enormous social and transport-related inequalities are observed. While essentially transport infrastructure investments and/or public transport reforms (e.g., Boquet, 2013; Regidor et al., 2017) have been discussed in the literature to address the transport woes in this region, a recent study highlights the existing demand and citizens' willingness to adopt MaaS (Hasselwander et al., 2022b).

The contribution of this paper to the scientific literature is threefold. First, we demonstrate the application of an accessibility calculation method that relies on global open data (described in Nieland et al., forthcoming), which especially developing cities can benefit from. Second, we contribute to the incipient literature on micro-mobility and MaaS in developing context, and provide empirical evidence and quantifications of integrated transport's potential benefits. Third, we contribute with a comprehensive and evidence-based policy discussion on how developing cities and transport authorities can foster MaaS, thus supporting a sustainable development and building more equitable transport systems.

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

## 2. Towards MaaS: the emerging mobility ecosystem

Urban transport is currently experiencing a major transition which harbors considerable potential to foster sustainable mobility (Creutzig et al., 2019). This transition is being triggered by technological trends (e.g., digitalization and electrification) as well as by societal and market changes (e.g., decarbonization and the rise of digital platforms), and has led to the development of new concepts of mobility – also labelled as New Mobility Services (NMS) (Cassetta et al., 2017). Although NMS typically emerge in developed lead markets, they quickly diffuse and establish globally including in the developing world (Hasselwander et al., 2022a).

Most NMS are built on the principle of (sequentially) sharing either passenger rides or vehicles. Sharing passenger rides – and in particular ride-hailing – has experienced tremendous success globally, due to the respective start-ups' aggressive expansion strategies into new markets, and leveraging excess capacity (Goletz and Bahamonde-Birke, 2021). However, despite its advantages (improved comfort and safety, reduction of parking requirements, etc.), these services are also linked to negative externalities. For instance, due

[1] In principal, this can be achieved through making additional transit stops and services available and/or through the provision of housing in proximity to the transit infrastructure. The latter, in particular, requires a substantial amount of time and financial resources.

[2] We support the view of Ferro et al. (2013) that public transport transformation projects do not require the formalization or substitution of paratransit services, and that they rather should be integrated with and complement (formal) public transport services.

to low access/usage barriers and rebound effects, it is argued that they increase overall vehicle-km travelled and thus contribute to traffic congestion and air pollution, among other negative externalities typically associated with cars (Tirachini, 2020).

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

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

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

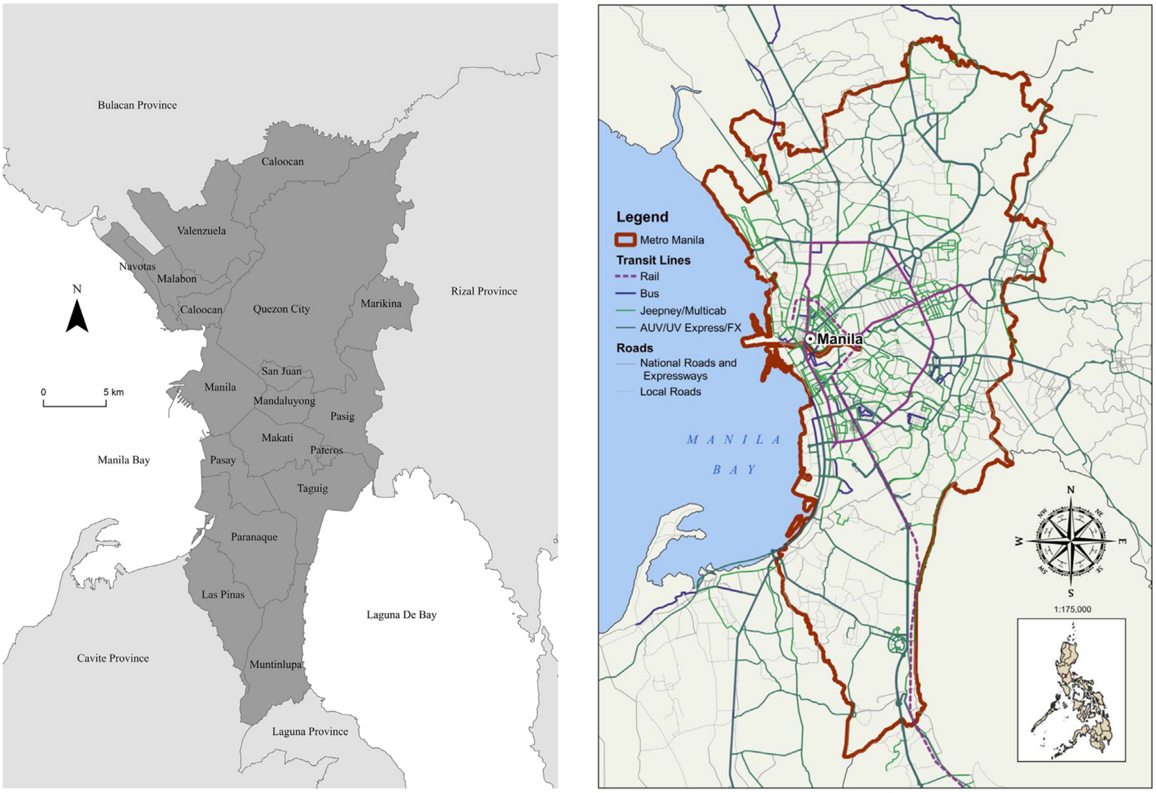
The integration of paratransit into MaaS has not been extensively studied yet. Similar to micro-mobility, paratransit often serves as a feeder to mass transit. It emerges wherever public transport services and infrastructure is lacking, and whenever excess capacity enables a profitable operation (Cervero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

## 3. Data and methods

### 3.1. Study area

Our study area is Metro Manila, the national capital region of the Philippines, located in Southeast Asia. Metro Manila comprises 17 cities and municipalities (Fig. 1a) and is one of the densest and most congested urban areas in the world. Several factors contribute to the region's notorious traffic gridlocks such as the lack of both high-capacity transport infrastructure (Fig. 1b) and integrated transport planning approaches. Induced by high birth rates and domestic migration, population settlements have spilled into the periphery and outside Metro Manila's administrative boundaries into adjoining provinces. Travel times and distances in this monocentric region are therefore steadily increasing (Andong and Sajor, 2017). Since low-income neighborhoods in the outskirts are mostly underserved by public transport, this holds particularly for those without access to private vehicles (Abad et al., 2019). According to results from a MaaS study in Metro Manila, the availability of first/last mile solutions would increase commuters' willingness to use public transport more often (Hasselwander et al., 2022b).

Despite high motorization rates, vehicle ownership in Metro Manila is still relatively low. According to a large-scale transport study, about 90 % of households do not have access to private vehicles (NEDA, 2014). Consequently, the majority of trips in the region is covered by public transport modes. Due to the fragmented rail network, there is a high dependence on road-based transit. In addition to buses and unscheduled shuttle services (called UV express), this mainly relates to the jeepneys – a local minibus version and the most dominant travel mode in the study area (NEDA, 2014). The different transport services are regulated by several authorities in a decentralized way, and without a holistic transport planning approach. This has resulted in redundant and overlapping routes and




a b

**Fig. 1.** (a+b). Political map of the 17 cities/municipalities forming Metro Manila (left) and the region's public transport network (right)
Source: Hasselwander et al., 2022b; Roquel et al., 2021.

disaggregated networks of the different transport services. The authors argue that the implementation of MaaS could be a potential solution to address these issues. Enabling seamless, intermodal trips in a fully integrated transport system under MaaS – i.e., ticket, payment, ICT, and mobility package integration of public transport, paratransit, and various NMS – would not only be a feasible and cost-efficient way to improve transit accessibility, but also to increase the quality of transport services as well as the network's overall efficiency and sustainability.

However, while ride-hailing apps (e.g., *Grab* and *Angkas*) enjoy great popularity in Metro Manila, more sustainable NMS are yet to be implemented on a larger scale. Even though privately owned e-scooters can occasionally be found on Metro Manila's streets, e-scooter sharing is still in its infancy in the region. Bike-sharing systems, such as the *UP Bike Share* at the University of the Philippines Diliman campus or the *Moovr PH* bike- and e-scooter sharing services in the business districts of Taguig City and Makati City, are only available to small potential user groups and with fragmented infrastructure. MaaS is a mainly unknown phenomenon in Metro Manila as well, although a MaaS pilot is currently in the discussion/planning stage for the City of Pasig as part of the EU-funded *SOLUTIONSplus* project (Panagakos et al., 2023).

### *3.2. Data sources*

In this research, we rely on three main data sources for our analysis. We utilize free and publicly available data that can also be obtained for many other cities worldwide. Therefore, our analysis could be easily replicated for numerous other cities.

First, for the population information, we use the population layer of the World Settlement Footprint 2019 (WSF-Pop 2019) data set. It provides a 10 m resolution global map of human settlements and distribution of the population on Earth, derived from optical and radar satellite imagery. More information on this data set, including the methods and its validation, is described in Marconcini et al. (2020). For the purpose of this study, we extracted the population raster for the Metro Manila region based on its political boundaries.

Second, we obtain the street network of Metro Manila from OpenStreetMap (OSM). OSM is a free editable geographic database of the world. The data is supplied by voluntary users based on a collaborative mapping approach. The Metro Manila street network in OSM is continuously maintained by an active mapping community and therefore expected to be very comprehensive and up to date. For example, the data set includes a distinction between public (i.e., accessible by pedestrians) and non-public roads, which is relevant for this study.

**Table 1**
Overview of model scenarios.

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Integrated transport modes | None | Public transport<br>Paratransit | Public transport<br>Micro-Mobility | Public transport<br>Paratransit<br>Micro-Mobility |
| Transit stops' catchment area | 500 m (walking) | 500 m (walking) | 500 m (walking)<br>2,000 m (e-scooter)<br>3,000 m (bicycle) | 500 m (walking)<br>2,000 m (e-scooter)<br>3,000 m (bicycle) |
| Description | The status quo: no integration, disaggregated networks of different transport services | Intermodal integration but without first/last mile | Intermodal integration but without informal modes of transport | Implementation of a full MaaS schemes that covers all public modes and micro-mobility for the first/last mile |

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

### 3.3. Measuring access to transit

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

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

We employ a similar proxy for calculating transit accessibilities under MaaS and the integration of paratransit (Scenario 2), with the addition of incorporating the locations of jeepneys stops.

For the analysis of Scenario 3 and 4, we expand the above definition and consider that public transport and paratransit services are not only accessible on foot but can also be combined with other modes and means of transport. As described in the background section, micro-mobility is considered an opportunity to address public transport's first/last mile problem and increase its catchment area.

The literature highlights that e-scooters are mainly used for short distances. According to large scale operational data from various service providers in Germany, e-scooters, on average, are used for trips up to approx. 2,000 m (Civity Management Consultants, 2019; cited in Laa and Leth, 2020), which aligns with analyses of the e-scooter market in the US (Sun and Ertz, 2022) and case studies in Asia (e.g., Cao et al., 2021).

Similarly, the usage patterns of shared bicycles seem to be heterogenous across different world regions, as reported in the study by Sun and Ertz (2022) that uses data from 39 cities covering three continents. On average, shared bicycle are used for trips between 2 and 4 km, which is shorter than trips with private bicycles. This is due to the fact that, among other reasons, shared bicycles indeed are frequently used to complement public transport trips on the first/last mile (Radzimski and Dzięcielski, 2021).

Although these figures still need to be validated in the context of a developing megacity, where shared micro-mobility options are currently not readily available, we argue that the international data reported in the literature is a good starting point to gain initial insights into an emerging market. Accordingly, for Scenario 3 and 4, we regard **2,000 m** as the maximum distance for feeder trips to be covered by e-scooters and **3,000 m** for bicycles.

Hence, we calculate transit accessibilities as:

$$TA_i = \frac{\sum_{j=1}^{n} h_j \times f\left(d_{hpj}\right)}{\sum_{j=1}^{n} h_j}, \forall i, j \tag{1}$$

with

$$f\left(d_{hpj}\right) = \begin{cases} 1 \text{ if } d_{hpj} \leq s \\ 0 \text{ otherwise} \end{cases}, s \in \ ]0, k] \tag{2}$$

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

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

### 3.4. Research Limitations

With regards to our research approach, it is important to note two key limitations. First, some data limitations can be expected due to incomplete and/or outdated data. Although the WSF2019-Pop data set builds on recent imagery data, population settlement patterns and urbanization in Metro Manila are subject to very dynamic developments. Also, it should be noted that the data set only provides an approximation of the household locations. Despite leveraging cutting edge technologies (e.g., the Copernicus satellites Sentinel-1 and Sentinel-2 for the radar imaging) and state-of-the-art machine learning techniques (Marconcini et al., 2020), inherent inaccuracies persist. Similarly, the GTFS data set does not reflect the latest public transport information. Especially since the COVID-19 pandemic, there have been several route adjustments and the introduction of some new services (e.g., the EDSA Carousel busway). However, in this research, we solely rely on the location of the transit stops. To the best of our knowledge, there have been minimal to no changes since the release of the data set relating thereto, which we have confirmed through validation with the data providers. Hence, we are confident that the data limitations only have a marginal effect on our study results.

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

## 4. Study results

Fig. 2 shows the transit accessibility index for Metro Manila under consideration of the different scenarios. A summary of the model results is shown in Table 2.

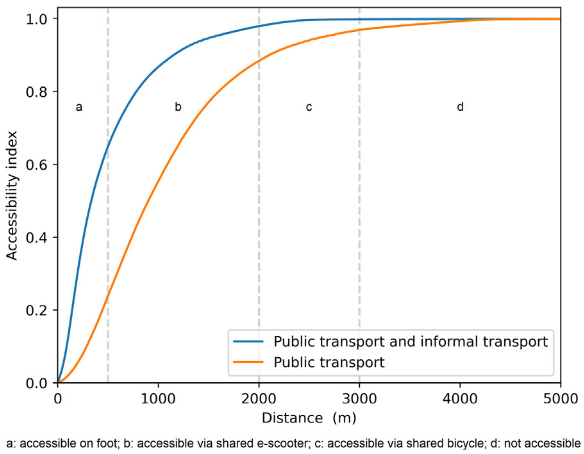



**Fig. 2.** Transit accessibility index for Metro Manila.

**Table 2**
Overview of model results.

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

For the baseline, we obtain a transit accessibility value of 0.239. Simply put, this means that only about 23.9 % of the Metro Manila population currently have convenient access to the transit systems (i.e., bus and rail) within 500 m walking distance. This value is significantly lower than the official SDG 11.2.1 value for Metro Manila (0.325). The deviation can be explained due to the different underlying data sources – note that instead of satellite imagery, household location data is usually derived from censuses or other demographic surveys – and calculation methodology as explained in Nieland et al. (forthcoming). For all households in Metro Manila, the mean distance to the closest transit stop is about 1,089 m, while the maximum distance according to our calculation is about 8,029 m.

In Scenario 2 – if paratransit would be integrated into the transit network – transit accessibility would almost triple to 0.650. The mean distance of all households to the closest transit stop would almost halve to about 564 m and the maximum distance decrease to approx. 6,765 m. In Scenario 3 – if micro-mobility is implemented as a feeder mode for public transport – transit accessibility would significantly increase to 0.884 (e-scooter) and 0.969 (bicycle), respectively. Almost the entire Metro Manila population (0.979 and 0.999, respectively) could have convenient access to transit, if micro-mobility would be available as a feeder for both public transport and integrated paratransit (Scenario 4).

The visualizations in Fig. 3 give further insights on transit accessibilities in the region. It shows that the centrally located parts of Metro Manila (e.g., Manila City, Mandaluyong, and Makati) currently provide a significantly better access to transit than cities located in the urban fringe (e.g., Valenzuela, Caloocan, and Muntinlupa) (Fig. 3a). Due to the concentration of work opportunities (e.g., in Metro Manila's three major central business districts BGC, Makati CBD, and Ortigas) as well as educational, cultural, and leisure facilities, these areas generate much of the region's trip demand. Hence, most of the bus operation origins/terminates in the center of Metro Manila, either on radial routes to/from the adjoining provinces or along the circumferential EDSA highway, the most important and frequented road in Metro Manila. Also, most of the current rail line operation (LRT1, LRT2, and MRT3) does not extend beyond the central areas of Metro Manila. Although the distance to transit stops in these areas are the shortest in the region, many households still do not have access to transit within walking distance. Residents in the periphery face even greater challenges in terms of access to the transit systems, as the closest bus and train stops are often located in more than 2,000 m distance.

The integration of jeepneys into the transit network would result in a much denser network (Fig. 3b), especially in the central part of Metro Manila. Paratransit could thus contribute to enabling a convenient access to the transit systems within walking distance for many residents in these areas. The integration of micro-mobility could additionally connect those citizens that reside in more

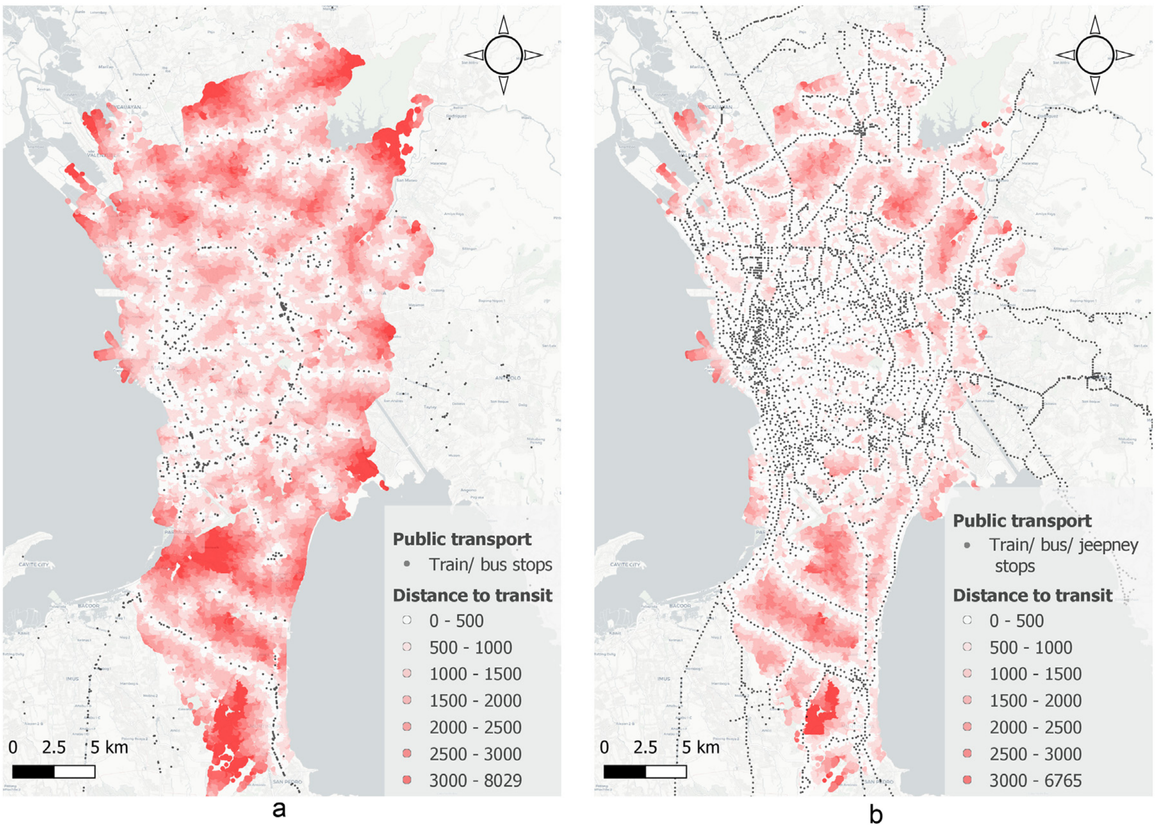



**Fig. 3.** (a+b). Transit accessibilities in the Metro Manila region: status quo with public transport (left) and with the integration of paratransit (right).

than 500 m distance to the closest transit stop. At the same time, micro-mobility could also serve as an effective alternative mode, particularly for short business trips within the CBDs.

On the other hand, despite the integration of paratransit, rather low access to the transit network would remain in the residential areas in the urban fringe. This includes both low-income, informal settlements as well as locally disembedded gated neighborhoods and wealthy subdivisions. In the former, vehicle-ownership is usually very low and residents often rely on local two and three-wheelers (*habal-habal* and tricycles) to get access to the transit network. In the latter, residents primarily depend on private vehicles. This phenomenon can be attributed to the prevailing perception of the private car as a status symbol, which is further reinforced by the inconvenient access to the transit network. Indeed, the subdivision development has segregated these areas from adjacent public road networks, leading to unnecessarily longer walking distances for accessing buses and jeepneys.

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

## 5. Policy recommendations

In the previous section, we outlined the locations and extent to which transit accessibilities in Metro Manila could be increased under MaaS. However, it is crucial to note that the results merely indicate potential accessibility gains if MaaS is fully implemented, paratransit fully integrated, and if micro-mobility options are readily available to users. Only when these conditions are realized can users truly benefit from seamless, multi- and intermodal trips and a better access to the transit network.

In the following sub-sections, we use the empirical evidence from our analysis to derive policy recommendations that we discuss against the backdrop of findings from the scientific literature. Specifically, we describe two fields of recommendations (Table 3) that cities and transport authorities can focus on to harness the transit accessibility potential under MaaS: namely (i) anticipate MaaS and support transport integration; and (ii) plan and stimulate the use of micro-mobility.

### *5.1. Anticipate MaaS and support transport integration*

A major stream in the MaaS literature focuses on governance issues and the role of the public sector. Case study results, primarily based on insights from Finland and other European countries, suggest that the public sector should take up an anticipatory role (e.g., Audouin and Finger, 2018; Mukhtar-Landgren and Smith, 2019). Building upon the lessons learned from the European context, Hasselwander and Bigotte (2022) argue that the public sector should also anticipate the MaaS development in the Global South. Indeed, market forces in the mobility sector tend to drive outcomes that are mainly profit-maximizing (Sareen et al., 2021). This was

**Table 3**
Overview of policy recommendations.

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

observed in the Philippines and other developing countries in the case of ride-hailing, where private sector leads have resulted in rather unsustainable transitions (Yuana et al., 2019).

Consequently, establishing a vision and a desired outcome under MaaS would be an important first step for the government as well as public transport operators and key MaaS stakeholders. We argue that this should be embedded at the highest level in the national transport strategy (although we recognize that the implementation should be a matter for subordinate authorities to take account of local specificities). In this context, the benefits of integrated transport and the promotion of multimodal travel alternatives (to the private car) should be clearly outlined. In the case of the Philippines, this was adopted in the National Transport Policy (NTP) and its Implementing Rules and Regulations (IRR) that envision "safe, secure, reliable, efficient, integrated, intermodal, affordable, cost-effective, environmentally sustainable, and people-oriented national transport system that ensures improved quality of life of the people" (NEDA, 2020).

MaaS also requires specific regulation and policy reforms (Li and Voege, 2017). The MaaS concept uncovers conflicts related to the legal definition of public transport and overall competition in the passenger transport market (Karlsson et al., 2020; Wilson and Mason, 2020). Legal concerns also arise regarding liabilities, risk sharing, passenger rights (Pagoni et al., 2020), data privacy (Cottrill, 2020), and so forth. Even though these conflicts seem to be less critical in the developing world context (Hasselwander and Bigotte, 2022), legislation changes and facilitating policies for MaaS are inevitable. Local authorities in Metro Manila, for example, are aiming for a reform of the current franchising model towards a Service Contracting Program (SCP), which was budgeted under the General Appropriations Act of 2021 (Dela Cruz, 2021). Since all road-based transport services are currently operated without subsidies and quality control, and are depending on private sector initiatives, this can be considered an important step to foster more efficiently organized transit services as the backbone of a MaaS scheme.

Other barriers for the MaaS transition have been identified as the degree of centralization of transport authorities and subordinated agencies as well as their entrenched structure and slow decision-making processes (Hasselwander and Bigotte, 2022). Hence, there is a need for institutional reforms and development to complement these efforts. For instance, a horizontal integration of institutions could facilitate the implementation of a large-scale transport project such as MaaS and enable centralized planning. In the particular case of Metro Manila, the establishment of a transport authority at Metropolitan level is thus recommended.

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

### 5.2. Plan and stimulate the use of micro-mobility

Amid the pandemic and social distancing measures, micro-mobility emerged rapidly as an efficient solution to provide mobility to people in many developing cities. Despite the controversies as discussed in Section 2, international best practices show how micro-mobility schemes – if matched with dynamic regulation and built on public-private partnership models – can be integrated in urban systems and enable just low-carbon mobility transitions (Sareen et al., 2021). Most importantly, enabling policies are needed to ensure safer space for lightweight vehicles and increase acceptance for micro-mobility as an alternative and complementary travel mode. In Metro Manila, the Land Transportation Office (LTO) has issued guidelines for the operation of electric light vehicles (Administrative Order 2021-039) that provide clear vehicle specifications (i.e., for e-scooter, e-bikes, etc.), as well as guidance on where (only on designated lanes) and how (defined speed limits, mandatory helmets, etc.) they can be used. However, the order restricts the operation to small local roads at *barangay* level (the smallest administrative unit). This significantly limits the range and makes many destinations inaccessible via such vehicles. Instead, a more permissive policy environment is recommended that supports a more equitable access to transport infrastructure (including for those without access to private cars) and allows potential operators to create a viable business model. Notwithstanding, regarding the parking of e-scooters, rather restrictive policies are advised to avoid conflicts in public space allocation and to avoid adversely impacting active transport (Laa and Leth, 2020). Parking should be limited to designated parking areas so that e-scooters do not emerge as additional hindrances and impair the walkability of sidewalks (that in many developing cities are often not well developed and maintained). Moreover, even though free-floating shared micro-mobility schemes provide more flexibility and some accessibility advantages (Brown, 2021), for a developing megacity such as Metro Manila, a station-based solution (with docking stations and/or bike racks) for accessing and returning shared e-scooter and bicycles is recommended. Regarding e-scooters, docking stations reduce interference in public spaces and therefore likely increase acceptance, and can recharge the vehicles if needed. Docking stations also reduce the planning and operational complexity of such systems, although intervention to address supply imbalances and to steer the spatial distribution of vehicles are inevitable (Brown, 2021).

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

Moving forwards, micro-mobility should be considered as an integral part of MaaS. This means that micro-mobility services should be locatable, bookable, and payable via a MaaS app. For trip requests, micro-mobility should be suggested as a travel alternative for short trips as well as a feeder for longer, intermodal trips. In addition to the “pay as you go” alternative, micro-mobility should also be included in mobility packages, if available. The included amount (either based on time or distance) should be defined in such way that micro-mobility can be established as an attractive alternative mode without cannibalizing active and public transport.

Due to financial and operational constraints, it should furthermore be noted that it is unlikely that sharing stations can be located in proximity to all households. It is therefore crucial to also encourage private ownership of micro-mobility through tax advantages, subsidies, or other incentives. Note that in Metro Manila, for instance, bicycle-owning households (36 %) already clearly outnumber households with access to private cars (11.5 %) (Siy, 2022). Policies that facilitate the combination of private micro-mobility trips with public transport should therefore have priority. For example, where feasible the opportunity to bring bicycles and e-scooters into buses and trains should be made possible. Also, sufficient bicycle racks and micro-mobility friendly infrastructure should be made available at major transit hubs and terminals.

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

## 6. Conclusion and future research

This research has performed an analysis on transit accessibilities in Metro Manila under MaaS. Our results highlight the importance of paratransit today (hence, the need to integrate it), and the potential role of micro-mobility in the future. Through the integration of these transport services, areas that are underserved by public transport can be connected to the transit network, which is a promising way to address latent demand, compensate for lacking transport infrastructure, and help realizing transit accessibilities comparable to those found in developed cities with extended mass transit systems. However, we stress that both facilitating and regulatory policies are needed to exploit this potential and ensure a more equitable access to the transit network in the long run. While the past has shown that transport innovations and accompanying policies in the Global South have often only been implemented hesitantly (Pojani, 2020), the COVID-19 pandemic has opened a ‘window of opportunity’ for Metro Manila and other developing cities to introduce unprecedented, structural changes in the transport sector (Hasselwander et al., 2021; Sunio and Mateo-Babiano, 2022). Indeed, in the immediate response to the crisis, significant shifts towards active mobility were observed, as well as shifts in policymakers’ priorities towards protecting public health (Sunio and Mateo-Babiano, 2022). Consequently, many policy implementations (service contracting of public transport, cashless payment systems, etc.) and infrastructure investments (dedicated active mobility lanes, BRT, etc.) have been introduced that in the future may facilitate the implementation of MaaS.

Additional studies are needed to reinforce our findings and provide further insights. A deeper investigation on accessibilities (e.g., using methods as described in Saif et al., 2019) is needed to analyze other limiting factors to access transit in the Global South. Moreover, the analysis should discriminate between different socio-demographic variables to understand (if and) how (in-)accessibility affects different segments of the population. While our results provide an idea about the potential transit accessibility gains under MaaS, in reality, however, there are diverse financial and operational constraints that hinder the wide-spread deployment of sharing-stations. Hence, future research should study the optimal location of $n$-number of sharing-stations to maximize overall transit accessibility. Also, potential mode substitution effects of micro-mobility in developing cities should be studied, and especially if users would replace car trips. Finally, we recommend investigating the integration of other NMS that have not been considered in the present study (e.g., ride-hailing and car-sharing).

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## CRediT authorship contribution statement

**Marc Hasselwander:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft. **Simon Nieland:** Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – review & editing. **Kathleen Dematera-Contreras:** Validation, Resources, Writing – original draft. **Mirko Goletz:** Conceptualization, Methodology, Writing – review & editing, Project administration.

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