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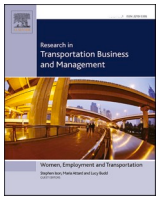

Framework for the potential userbase of mobility as a service

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ABSTRACT

When a Mobility-as-a-Service (MaaS) implementation is planned, the potential userbase must be understood to determine the service potential. The characteristics and travel behaviour of the potential users to estimate the userbase for a MaaS service is not well understood. Additionally, studies in the developing country context are limited. This research has developed a framework to derive an understanding of the potential userbase using population as well as travel mode perspectives with a focus on developing countries. The framework was developed through literature to better understand the characteristics of a potential MaaS user to evaluate the potential userbase. The population perspective includes socio-demographic factors, subjective attitudes and perceptions and environmental considerations of a developing country MaaS user. The perspective of the travel mode includes travel demand and travel mode characteristics of a typical MaaS user. The framework was cross-validated with pilot MaaS studies to affirm and expand the various characteristics presented. Furthermore, a practical implementation of the framework was discussed to aid potential developing country MaaS operators and transport planners to understand the potential userbase for MaaS and to evaluate its potential success.

1. Introduction

Imagine a world without private vehicles – a world where you can travel to your destination using any combination of transport modes, such as buses, trains, taxis, ride-hailing and many more, without the need to book a taxi, have a bus ticket, check the train schedule or own a car. This concept is known as Mobility-as-a-Service (MaaS) (Hietanen, 2014; Ho, Hensher, Mulley, & Wong, 2018; Jittrapirom et al., 2017). MaaS is an integrated transport solution that combines different transport modes in a single mobility package which can be accessed with a single interface. The single interface, which could be accessed via the web or an application on an electronic device, can consist of multiple applications such as trip planning, bookings and payments (Ambrosino, Nelson, Boero, & Pettinelli, 2016; Hietanen, 2014). The core function of MaaS is to fulfil the mobility needs of users by offering flexible, reliable and seamless door-to-door transport options to reduce congestion and pollution (Mulley, Nelson, & Wright, 2018; Utriainen & Pöllänen, 2018).

MaaS research has previously focused on evaluating the levels of integration of MaaS schemes (Kamargianni, Li, Matyas, & Schäfer, 2016), the MaaS product bundles (Matyas & Kamargianni, 2018), or which type of governance is most suitable for MaaS (Audouin & Finger, 2018). In terms of the MaaS user, the perspective of the user (Weckström et al., 2018) and the willingness of the users to pay for the service (Ho et al., 2018) have been reviewed. The reasons for using the service as well as expected benefits have also been researched (Polydoropoulou, Pagoni, & Tsirimpa, 2018; Sochor, Strömberg, & Karlsson, 2015). However, there is little understanding of how MaaS schemes will be adopted by the users (Ho et al., 2018). Ho et al. (2018) and Jittrapirom, Marchau, Heijden, and Meurs (2018) call for the demand-side modelling of MaaS through studies that investigate the potential uptake and market for MaaS adoption. A more detailed analysis is required of the characteristics and travel behaviour of the user to better understand the potential userbase (Weckström et al., 2018). Moreover, MaaS studies in the developing country context are limited and attention should be given to assist these economies through improved transport infrastructure (Singh, 2020). There is therefore a research gap with regard to the knowledge of the characteristics of a typical MaaS user (Ryley, Stanley, Enoch, Zanni, & Quddus, 2014) to enable a better understanding of how MaaS will be adopted by its potential userbase in a developing country context.

The aim of the research was to *provide a framework to determine the potential MaaS userbase in a developing country using the characteristics of a typical MaaS user.*

The structure of the article is as follows: An overview of existing

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MaaS frameworks are presented in Section 2 to understand what information is used in these frameworks. The research approach used to formulate the potential MaaS user framework is described in Section 3. The construction of the potential MaaS user framework is presented in Section 4. Section 5 cross-validates the potential MaaS user framework with literature focused on MaaS pilot studies. Section 6 demonstrates the practical application of the potential MaaS user framework and Section 7 concludes with the contributions to scholarly knowledge.

2. Existing MaaS user frameworks

Frameworks are used to evaluate the impact of mobility schemes on the travel behaviour of the individual (Jain, Johnson, & Rose, 2019). A theoretical framework for the impact of car sharing on travel, lifestyle and mobility choices is provided by Jain et al. (2019). The framework uses the adoption of car share, which is dependent on psycho-social factors, and the availability of car share as inputs to determine the changes in lifestyle, mobility and travel choices involved in car-sharing schemes.

Travel choice factors are used in another framework that focuses on the design of the supply side of mobility services (Liu, Bansal, Daziano, & Samaranayake, 2019). The framework is used to design, optimise and analyse mobility operations. With regard to the demand side, the research by Arroyo, Ruiz, Mars, and Serna (2018) provides a general travel behaviour framework that focuses more on the demographics and the travel behaviour of the individual. The framework describes how certain values, attitudes and social influence contribute to demographics and travel behaviour and how they interact with each other.

Rojas López and Wong (2019) evaluated travel behaviour theories and frameworks in order to determine process and determinants of mobility decisions. This travel behaviour framework consists of processes and determinants that affect mobility decisions which could be dynamically modified in different scenarios. The evaluation of the potential demand uses forecasting models (Hidaka & Shiga, 2018) that are based on the personal attributes of the individual, the activity, the destination and the travel modes. Simulation studies such as agent-based models also make use of the travel behaviour of each user to evaluate potential demand (Dia & Javanshour, 2017).

The existing frameworks discussed illustrate the importance of the travel behaviour factors in creating a framework to evaluate the potential demand for MaaS. However, these frameworks provide a limited description of the characteristics of a MaaS user. This research addresses the gap by building on the various frameworks to describe the characteristics of a typical MaaS user using travel behaviour factors.

3. Research approach

The research approach used to identify the characteristics of the potential userbase of MaaS is shown in Fig. 1. The first task was to perform a literature review to identify which factors influence a person's choice to use a certain transport mode, i.e. travel choice and behaviour factors. Following this, the characteristics of typical mobility users were identified from literature on users from existing MaaS schemes and other mobility schemes such as bus rapid transport, e-biking and other demand-responsive transport services. The characteristics identified from the different studies were mapped into the travel choice and behaviour factors to determine the characteristics of a typical MaaS user. These characteristics are presented in a format that could be used to evaluate the potential userbase.

3.1. Travel behaviour factors of users

Transport operators need to know the travel behaviour of individuals for planning and policy analysis (Kitamura, 1988). Travel behaviour factors are used to determine how people use different transport modes as well as when and where they travel. The travel behaviour of the population can be affected by three main categories, namely travel components, external factors and internal factors (Veterník & Gogola, 2017). The travel behaviour factors presented in this research have a demand-side modelling focus to investigate the potential uptake and market for MaaS adoption (Ho et al., 2018; Jittrapirom et al., 2018). It is important to articulate the factors that affect the travel mode such as travel demand and various travel mode characteristics. The rest of the external factors consist of policies, environmental considerations and economic factors. The internal factors are related to the characteristics of the individual, such as their socio-demographics and subjective attitudes and perceptions (Veterník & Gogola, 2017; Yang, Wang, Liu, & Zhou, 2018). For this research, the travel components, internal factors and environmental considerations of the external factors were used to describe the characteristics of a typical MaaS user and to evaluate the potential MaaS userbase. The external factors, such as policies and economic factors, were beyond the scope of this research as these cannot be controlled by the individual, but are determined by the government and transport agencies (Veterník & Gogola, 2017). The potential MaaS userbase can be determined using the travel component factors which can be seen from the perspective of the travel mode. The internal and

Table 1
Factors for travel behaviour (Veterník & Gogola, 2017; Yang et al., 2018).

Perspective	Factor	Travel behaviour factor
Population	Socio-demographics	Internal
	Subjective attitudes and perceptions	Internal
	Environmental considerations	External
Travel mode	Travel demand	Travel component
	Travel mode characteristics	Travel component

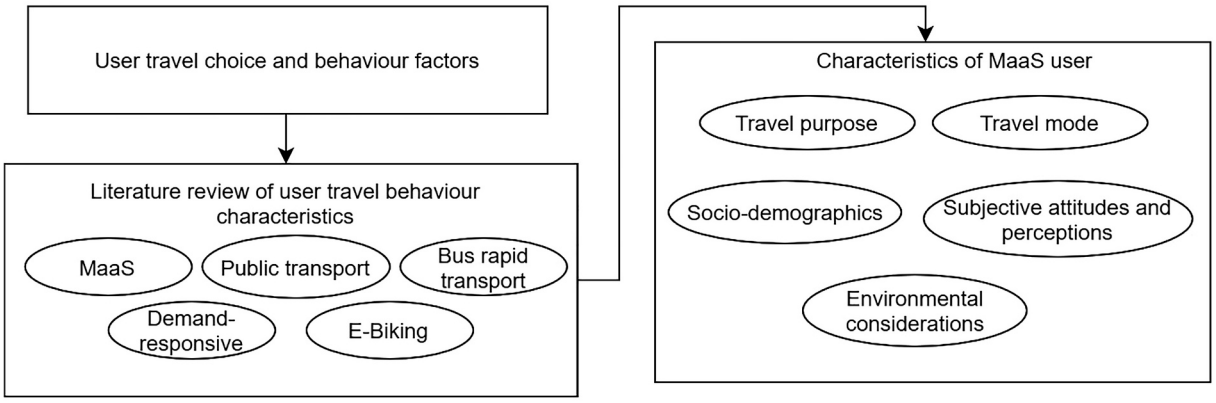

Fig. 1. Research approach.

external factors can also be used to determine the potential userbase, which can be seen from the perspective of the population, as shown in Table 1 (Veterník & Gogola, 2017; Yang et al., 2018).

4. Potential MaaS userbase

4.1. MaaS user from the perspective of the population

The perspective of the population focuses mostly on the internal factors of the traveller, such as socio-demographic characteristics, attitudes and perceptions and environmental considerations.

Several of these are discussed below. The discussion includes the overall effect of the specific factor on general travel behaviour as well as how the specific factor will affect a potential MaaS user.

4.1.1. Socio-demographic factors

Socio-demographic factors have a direct influence on the travel mode a person uses. These factors include the person's age, gender, income, education and more factors that are relevant to the individual (Kattiyapornpong & Miller, 2009; Yang et al., 2018). The main socio-economic and demographic factors and their impact on travel behaviour were evaluated by Veterník and Gogola (2017).

In general, the age of a user influences a person's travel mode decision (Ho et al., 2018; Veterník & Gogola, 2017). This is because people of different age groups, such as children, adults and older people, have different reasons for travelling (Veterník & Gogola, 2017). The literature suggests that younger people, especially millennials and generation Z, are more likely to use mobility schemes and be the early adopters of MaaS. This is most likely due to the difference in the generations concerning digital technology (Alemi, Circella, Handy, & Mokhtarian, 2018; Dias et al., 2017; Jittrapirom et al., 2018; Young & Farber, 2019). The Kutsuplus pilot in Finland was evaluated by Weckström et al. (2018) and they suggested that the service could be used by all ages. However, they also found that young users with a low income were more likely to not use the specific service. This could be due to the different channels used for data collection, such as emails to registered users, and specific social media groups.

Gender plays a role in the travel behaviour of people as females tend to travel more frequently but over shorter distances compared to males. This is because they are more likely to travel for shopping purposes or taking children to school (Veterník & Gogola, 2017). Gender does not play a role in impacting MaaS subscriptions or using mobility schemes such as ride-hailing services (Ho et al., 2018; Weckström et al., 2018; Young & Farber, 2019), but males are more likely to use bus rapid transit (BRT) services (Bartels, Kolbe-Alexander, Behrens, Hendricks, & Lambert, 2016). Overall, although MaaS may be used differently by the different genders, it will still be used by both genders.

Household income affects the travel behaviour of individuals. People with a higher income generally have more money to spend on travel and are therefore able to travel more (Veterník & Gogola, 2017). Mobility schemes are used by all income groups (Weckström et al., 2018), although there is a higher adoption rate and userbase for high-income households (Alemi et al., 2018; Young & Farber, 2019). Individuals in the lower income group are more likely to walk or use bicycles than other income groups (Zhao, Nielsen, Olafsson, Carstensen, & Meng, 2018). The first adopters of MaaS will have a high income as MaaS schemes will also be implemented first in high-income areas and countries. This could be a concern for mobility services in developing countries as they do not cater for the lower income users, as also highlighted by Young and Farber (2019). Several variations of MaaS could be adapted to cater for lower income populations and countries.

The use of cars decreases as the level of education increases since it is suggested that the negative effects of car use might be better recognised with education (Yang et al., 2018). The use of mobility services will also be better utilised by users with a high level of education as they have the ability to be more adapted to technology and are more aware of these services (Dias et al., 2017). The first adopters of MaaS will most likely be individuals with a higher level of education (Alemi et al., 2018; Dias et al., 2017).

The employment level of a person also plays a role in their travel behaviour. People who are part-time or unemployed are less likely to use mobility schemes as they have little or no reason for travelling (Dias et al., 2017). However, students and full-time employees are more likely to be users of mobility schemes and have a higher adoption rate (Alemi et al., 2018; Dias et al., 2017). Full-time employees would use mobility services due to work-related activities (Dias et al., 2017). This particularly true for students who work and study (Alemi et al., 2018).

Car ownership provides users with more travel options, more mobility and more independence (Luke, 2018) than the general public transport system. Car ownership does play a role as users with easy access to a car prefer the freedom it gives (Jittrapirom et al., 2018), whereas infrequent car users are more likely to use the service (Ho et al., 2018). Therefore, car ownership in households can play a role in MaaS, but their use of MaaS depends on other factors such as the population density of the area and household size (Dias et al., 2017).

The number of people in the household plays a role in the transport mode a person uses. Households with several children prefer a private vehicle as it is considered to be more convenient (Ho et al., 2018). The literature suggests that the number of people in a household plays a role in determining MaaS subscribers, as small households are more likely to use the service than those with more children (Ho et al., 2018). This is supported by other studies that show that even in the middle-income categories, participation in mobility schemes declines when there are more children in the household. This is because the convenience of a private car in a larger household makes it less likely for the users to use other forms of transport (Dias et al., 2017; Zhao et al., 2018).

It can therefore be seen that car ownership, the number of people in the household and the income level of the household are all related to each other and combine to determine whether a person will be a potential MaaS user. The first adopters of MaaS are most likely people with a high income, who live in a small household and do not own a private car.

Table 2 shows a summary of the socio-demographic characteristics of a typical MaaS user from the perspective of the population.

Table 2
Summary of socio-demographics.

Main factor	Attribute	MaaS user characteristics
Socio-demographics	Age	Young people most likely users (Alemi et al., 2018; Bartels et al., 2016; Dias et al., 2017; Ho et al., 2018; Weckström et al., 2018; Young & Farber, 2019; Zhao et al., 2018)
	Gender	Used equally by both genders (Bartels et al., 2016; Ho et al., 2018; Weckström et al., 2018; Young & Farber, 2019)
	Income	Higher adoption by high-income households (Alemi et al., 2018; Bartels et al., 2016; Young & Farber, 2019)
	Education level	Used by people with a higher level of education (Alemi et al., 2018; Dias et al., 2017; Young & Farber, 2019; Zhao et al., 2018)
	Employment status	Used by students and full-time employed workers (Alemi et al., 2018; Dias et al., 2017; Zhao et al., 2018)
	Car ownership	Does play a role (Alonso-González, Hoogendoorn-Lanser, Van Oort, Cats, & Hoogendoorn, 2020; Storme, De Vos, De Paepe, & Witlox, 2020)
	# of people in household	Higher adoption by small households (Dias et al., 2017; Ho et al., 2018; Zhao et al., 2018)

4.1.2. Subjective attitudes and perceptions

Subjective attitudes and perceptions of the user include their attitudes towards certain transport modes as well as their beliefs regarding technology and the environment. Users experience certain travel modes differently and have different feelings regarding the comfort, safety, reliability and importance of the different travel modes (Yang et al., 2018).

Technology adaptation is usually not a factor in determining a person's travel choice, but it has been found to play a role in the adoption of mobility schemes such as ride-hailing. This is because individuals who embrace a technologically driven lifestyle, through the use of social media and smartphones, are willing to take a risk with the adoption of a new service (Alemi et al., 2018; Dias et al., 2017; Jittrapirom et al., 2018). Potential MaaS users will be individuals who use and adapt easily to technology by having access to a smartphone and the internet.

Private cars provide a sense of freedom and independence to an owner and car users will not switch easily to MaaS (Jittrapirom et al., 2018). MaaS can, however, reduce car ownership in that the user is not tied down to a car loan and has no obligation to service the car and keep an up-to-date car licence (Whittle, Whitmarsh, Hagger, Morgan, & Parkhurst, 2019). The general view is that public transport does not meet the mobility, accessibility, travel requirements, affordability and status need of the user (Kroesen & Chorus, 2018; Luke, 2018). However, regular public transport users are expected to also be one of the first adopters of MaaS since they will be more familiar with using different modes of transport (Jittrapirom et al., 2018).

Table 3 shows a summary of the subjective attitudes and perceptions of a typical MaaS user from the perspective of the population.

4.1.3. Environmental considerations

The operating environment within which MaaS would potentially operate needs to be considered. Mobility schemes tend to be more successful in dense, populated areas. Areas where there are more ride-hailing trips are campuses, business areas and residential areas. The outlying areas have fewer trips (Alemi et al., 2018; Weckström et al., 2018). Accessibility to nearby schools increases the likelihood that children will walk or use a bicycle to commute to school. Nearby access to public transport will also increase the likelihood of using e-bikes (Zhao et al., 2018). The research by Jittrapirom et al. (2018) indicates that MaaS will most likely be implemented in urban areas initially because the required transport infrastructure, technology and institutions are already developed and available there. The development of the service level of MaaS in rural areas up to the level of urban areas will also be a challenge due to the infrastructure and technology requirements (Jittrapirom et al., 2018).

Table 4 shows the characteristics that describe the environmental considerations of a potential MaaS user based on the perspective of the population as obtained from literature.

4.2. MaaS user from the perspective of the travel mode

The perspective of the travel mode focuses on travel component factors such as travel demand and travel mode factors. How these factors affect travel behaviour in general as well as for MaaS is discussed below.

Table 3
Summary of subjective attitudes and perceptions.

Main factor	Attribute	MaaS user characteristics
Attitudes and perceptions	Technology adaptation	Technologically driven individuals have higher adoption rates (Alemi et al., 2018; Dias et al., 2017)
	Transport mode attitude	Positive attitude towards public transport (Jittrapirom et al., 2018)

Table 4
Summary of environmental considerations.

Main factor	Attribute	MaaS user characteristics
Environmental considerations	Neighbourhood type	Dense, populated areas such as business areas, campuses and residential areas (Alemi et al., 2018; Weckström et al., 2018; Zhao et al., 2018)
	Urbanised setting	MaaS is more likely to be implement first in urban areas as the infrastructure is already in place (Jittrapirom et al., 2018)

4.2.1. Travel demand

Travel demand characteristics involve the purpose of the trip. The trip purpose is the reason for travelling, such as going to work, shopping or for leisure purposes (Yang et al., 2018). The most common reason for using MaaS is to commute to work, to school and for social or recreation trips (Bartels et al., 2016; Jittrapirom et al., 2018). Business travellers often do not have access to their car and must make use of the service for work-related activities. Mobility services for social or recreation trips are mostly used in the evenings since travellers going out at night for recreational activities use the service to travel safely (Alemi et al., 2018; Dias et al., 2017; Jittrapirom et al., 2018; Weckström et al., 2018). BRT services are used mostly for commuting to work, followed by recreational and general activities. The potential MaaS user will therefore use the service to go to work, for business trips, to go to school and for social trips.

Table 5 shows a summary of the travel demand information of a typical MaaS user from the perspective of the travel mode.

4.2.2. Travel mode characteristics

The characteristics of the travel mode also play a role in the travel behaviour of users. This is because different travel modes have different characteristics, such as different cost, safety features, travel times and service quality. Users prefer a travel option that has a shorter travel time, low cost, is safe and comfortable and provides flexibility and convenience (Yang et al., 2018). Furthermore, the cost of the service needs to be considered in lower income households as affordability is essential for potential MaaS uptake (Bartels et al., 2016; Dias et al., 2017). Transport cost is one of the main reasons for using BRT services. Other reasons for using BRT services are safety, on time due to dedicated bus lanes and for more comfort (Bartels et al., 2016).

Service quality factors such as vehicle unavailability, inaccurate travel times and long response times can cause frustration for the user and lead to a decision to stop using a transport mode (Hesselgren, Sjöman, & Pernestål, 2018; Weckström et al., 2018). A near door-to-door service such as a commuter bus service is used for short-distance travelling and is convenient for end-users if the service pick-up points are nearby. Reliable services are also considered to be comforting with ergonomic seats and less noise disturbances. Flexibility and cost can, however, make users use other services such as a private car. The reliability of public transport systems can influence the user to decide to use their car as an alternative. This is an indication that the transport modes for MaaS should be able to provide similar service quality, convenience and reliability as private vehicles in order to cater for the potential userbase (Hesselgren et al., 2018; Weckström et al., 2018).

Table 6 shows a summary of the travel mode factors that describe a

Table 5
Summary of travel demand.

Main factor	Attribute	MaaS user characteristics
Travel demand	Travel reason	To commute to work, business trips, to go to school and for social or recreation trips (Jittrapirom et al., 2018)

Table 6
Summary of travel mode.

Main factor	Attribute	MaaS user characteristics
Travel mode	Cost	Affordable cost for the service (Bartels et al., 2016)
	Service quality	Service quality, availability and timeliness are important (Hesselgren et al., 2018; Weckström et al., 2018)
	Convenience and reliability	Convenience and reliability can retain users (Hesselgren et al., 2018; Weckström et al., 2018)

potential MaaS user based on the perspective of the travel mode.

4.3. The characteristics of a potential MaaS user

The potential MaaS user framework is shown in Fig. 2 and is obtained from combining the characteristics of a MaaS user from Table 4 to Table 6. The characteristics of the potential user are shown from the population perspective, and the travel mode perspective gives an indication of how the user will use the service and what factors are important for the travel mode. The potential MaaS user framework provides a better understanding of the potential userbase and can be used to identify and evaluate this userbase for MaaS.

5. Cross-validating the potential MaaS user framework

In order to confirm validity, the potential MaaS user framework (Fig. 2) was compared against pilot studies in developed and developing countries. This comparison was done both from the population as well as the travel mode perspective. The comparison was made using four pilot studies done in Europe (developed countries) and one in India (Singh, 2020) (developing country). The European nations represented in Table 7 include Sweden (Strömberg, Karlsson, & Sochor, 2018), the Netherlands (Alonso-González et al., 2020), Germany (Schikofsky, Dannewald, & Kowald, 2020) and Belgium (Storme et al., 2020). Table 7 provides a comparative overview from the potential MaaS user population perspective.

From the population perspective comparison, the European pilots indicate that the user age can range from 18 to 49, implying that MaaS adoption is not limited to young users. The population perspective of the potential MaaS user framework contradicts the developed country age range as it argues that young users are most likely to adopt MaaS in a developing country context. The pilot studies provide practical context and suggest that the userbase could be expanded to include a wider age range. However, there must be awareness in the South African context of the high youth unemployment rate (Patel, Khan, & Englert, 2020) which could also suggest a wider, mature age range for MaaS adoption. In line with pilot studies, the potential MaaS user framework confirms that socio-demographics associated with tertiary education, an urban living environment, gender neutrality and co-habitation with/without children are characteristics of a developing country MaaS user. Conversely, the potential MaaS user framework includes users from the higher income group as these are individuals with higher quality jobs and full-time employment. Developing countries have high levels of income inequality (Kollamparambil, 2020; Van Der Hoeven, 2019), making it less feasible to realise widespread MaaS adoption while using the current transport infrastructure. The potential MaaS user framework addresses a potential weakness of Singh (2020) as it includes socio-demographics within a developing country context.

The pilots in Belgium, the Netherlands and Sweden reveal how public transport usage has increased and is viewed more favourably. Public transport in the developing country context is generally not viewed positively and is used only where and when needed (Ashmore, Pojani, Thoreau, Christie, & Tyler, 2019; Hlubi & Seftel, 2019). This is further discussed under the travel mode perspective. Both developed and developing countries argue technology as a fundamental driver for MaaS adoption. Technology such as smartphones and mobile broadband are pivotal as MaaS users require this to plan and manage their trip configurations. However, technology adoption is more prevalent among younger South Africans and the MaaS userbase is expected to be concentrated in the 20–34 age range. Alternatively, technology adoption could arguably be more important than age as MaaS adoption is technology driven in the pilots in India, the Netherlands and Sweden. Next, Table 8 provides a comparative overview from the potential MaaS user travel mode perspective.

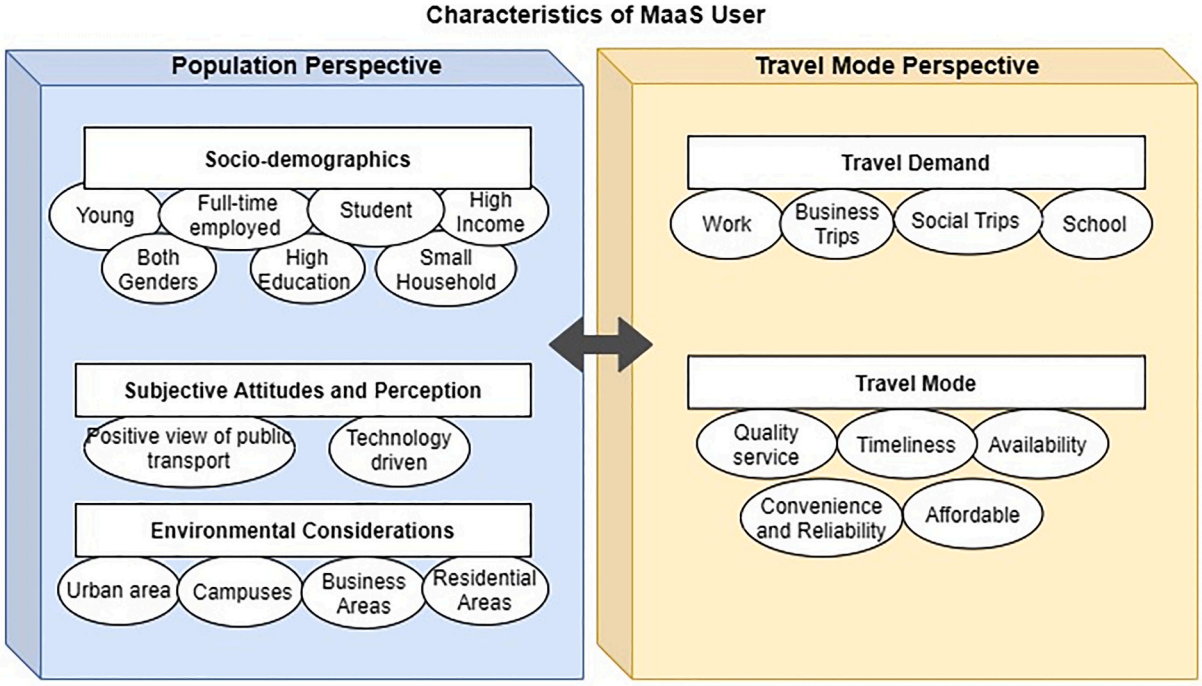

Fig. 2. Potential MaaS user framework.

Table 7
Potential MaaS user framework population perspective – comparison to pilot studies.

Reference	Age	Income level	Education -tertiary	Environment	Gender	Household composition	Public transport perception	Technology driven
Strömberg et al. (2018)	19–44	Medium to high	x	Urban	Neutral	Co-habiting with/ without children	+	+
Alonso-González et al. (2020)	18–49	Medium to high	x	Urban	Neutral	Single	+	+
Schikofsky et al. (2020)	18–39	Medium to high	x	Urban	Neutral			
Singh (2020)								+
Storme et al. (2020)	25–44	Low to medium	x	Urban	Neutral	Co-habiting with/ without children	+	
Potential MaaS user framework	20–34	High	x	Urban, campuses, business areas, residential areas	Neutral	Co-habiting with/ without children		

Table 8
Potential MaaS user framework travel mode perspective – comparison to pilot studies.

Reference	Transport modes										
	Auto-rickshaw	Bike share	Boat	Bus	Car pool	Car share	Ferries	Ride-hail	Train	Tram	Taxi
Strömberg et al. (2018)		X		X		X	X		X	X	X
Alonso-González et al. (2020)		X		X	X	X		X	X	X	
Schikofsky et al. (2020)											
Singh (2020)	X	X	X	X					X		X
Storme et al. (2020)		X		X		X			X	X	X
Potential MaaS user framework				X				X	X		X

The European countries studied are considered developed countries with robust infrastructure (Alonso-González et al., 2020; Schikofsky et al., 2020; Storme et al., 2020; Strömberg et al., 2018). Currently, only Singh (2020) has explored the possible implementation of MaaS from a developing country perspective with a study on the possible transport modes and configuration for MaaS in the Indian city of Kochi. From the travel mode perspective, there is clear variation of available transport modes and their inclusion in a MaaS configuration. The European nations have similar transport modes available. In a developing country such as India, transport modes include intermediate public transport modes such as rickshaws, seven-seater vans and minibuses (Singh, 2020). This initial difference highlights how developing countries need to be cognisant of indigenous transport modes to develop a MaaS system that suits local travel preferences and options. In the South African context, there are four main transport modes available: bus, ride-hailing, taxi and train. For example, Rea Vaya in Johannesburg consists of 325 km of BRT to provide transportation to approximately 80% of the Johannesburg population. The Gautrain is a high-speed rail service that connects OR Tambo International Airport, the metropolitan area of Tshwane and Johannesburg. Similar to the Indian context, intermediate transport dominates as minibuses serve as the main transport mode for many locals.

Something that is not clearly articulated in the pilot studies is the travel demand/reason, i.e. the reason or purpose for the user to travel. At a high level, Storme et al. (2020) found how personal cars are preferred for social and school-related trips and how MaaS is not seen as a complete substitute when travelling with children in particular. Conversely, Strömberg et al. (2018) reveal how MaaS configurations around public transport are preferred as it is more cost and environmentally effective. Alonso-González et al. (2020) refer to work trips where MaaS is considered a suitable and viable alternative for daily commutes to and from work. Schikofsky et al. (2020) and Singh (2020) do not present arguments for travel demand/reason and rather focus on general MaaS motivational factors and conceptual MaaS attributes, respectively. The potential MaaS user framework thus adds a new perspective regarding travel demand/reason, as arguments should be made for how MaaS can be implemented and configured for various travel demand/reason.

Attributes relating to cost, quality, convenience, reliability and availability should also be considered from a travel mode perspective. Alonso-González et al. (2020) note the importance of these attributes to understand MaaS adoption. The Netherlands pilot study explicitly acknowledges these attributes and supports including them within a developing country context. Given the infrastructure variance in developing countries, these attributes cannot be overlooked. As noted previously, there is generally a negative perception of public transport in the developing country context. For example, the commuter taxi industry is the most dominant public transport mode in South Africa and is heavily concentrated in urban areas where the normal trip is short distances in high-density corridors (Kroesen & Chorus, 2018). The service does, however, have a poor safety record and there are problems around vehicle roadworthiness and reckless driving (Vanderschuren & Baufeldt, 2018). Furthermore, current public transport services are plagued by poor service quality, availability and reliability (Gumbo & Moyo, 2020; South African Government, 1996). Alternatively, Uber and other ride-hailing services are complementary to other public transport modes such as the Gautrain and bus services by providing last-mile or first-mile transportation services (Acheampong, Siiba, Okyere, & Tuffour, 2020). Moreover, ride-hailing services are used by locals that traditionally would avoid public transport and use private vehicles for social and business trips (Smith, 2019). While ride-hailing services address issues around service quality, availability and reliability, they are not as cost effective as public transport and are used by higher income groups locally (Smith, 2019; Tirachini, 2020). These on-demand services could be perceived as premium and costly services (Alonso-González et al., 2020).

Developed countries have similar infrastructure configurations, making it easier to identify potential MaaS configurations and users. However, developing countries have varying infrastructures that do not exhibit similar designs or are not conducive for a rapid shift to MaaS. It is therefore essential to understand a developing country's travel mode and population perspective (Table 7) to determine the potential user-base to develop infrastructure conducive to MaaS adoption. The potential MaaS user framework presented in this research expands on the developing country perspective by acknowledging the relevance of transport modes and how they influence MaaS adoption.

6. Applying the potential MaaS user framework to estimate potential userbase

The potential MaaS userbase framework (Fig. 2) provides an overview of the characteristics of a MaaS user in a developing country context. Expanding on the framework, Fig. 3 illustrates how to adopt and apply the framework practically.

The first step of the application is the environmental consideration, which entails identifying the specific target area, such as the province of Gauteng in South Africa, for determining the potential MaaS userbase. It is important to note that several statistics about the population and travel modes within the target area have to be available. For example, reports such as the National Household Travel Survey and Community Survey can be used as a source to gather and extrapolate the required population statistics and characteristics. In cases where data is unavailable, it is suggested that data from similar target areas can be used as long as it is motivated and relative.

Once the target area has been identified, the potential MaaS userbase can be evaluated from the population perspective and the travel mode perspective as described below:

Population perspective

1. Obtain population statistics: Obtain these from census data or surveys for the specific target area. The data or surveys must relate to the population perspective factors of the potential MaaS user framework (Fig. 2).
2. Quantify factors: Quantify the population perspective factors from the potential MaaS user framework (Fig. 2) into specific categories to compare them to the statistics obtained of the target area in step 1. The quantification process has numerical bands for these factors, such as the high-income factor to a specific household income range, and the young factor to a specific age range.
3. Identify users with MaaS socio-demographic profile: Use the quantified factors of step 2 as the criteria for a typical MaaS user. These factors must relate to the population perspective factors of the potential MaaS user framework (Fig. 2). Use the criteria to find the percentage of the population that meets the criteria for a typical MaaS user.

Travel mode perspective

1. Identify travel modes: Investigate and identify the available travel modes within the target area that could be used as a potential MaaS travel mode. All available travel modes, excluding private travel, can be included as the viability of each is assessed in later steps.
2. Obtain travel statistics: Obtain the travel statistics of the chosen travel modes within the target area that relate to the factors identified in the potential MaaS user framework (Fig. 2) and the trip frequency information.
3. Identify possible service configurations available: Using the identified travel modes within the target area, identify all possible combinations of travel modes of how a user can use the service, e.g. the user can use a taxi, then the train and then a ride-hailing service or just the bus with an e-biking service.
4. Estimate demand: By using the travel statistics of the different travel modes such as the trip frequency per user for each travel reason, estimate the number of trips and users for each possible service configuration for each possible travel demand/reason in the potential MaaS user framework (Fig. 2).
5. Analyse viability of demand: Evaluate the viability of all the trip configurations in terms of the travel mode factors of the framework such as costs, timeliness, quality, availability and convenience.

The final potential userbase is determined by combining and analysing the results obtained from the population perspective and the travel mode perspective. This will give a broad overview of the potential userbase of MaaS in the target area. The analysis can be evaluated

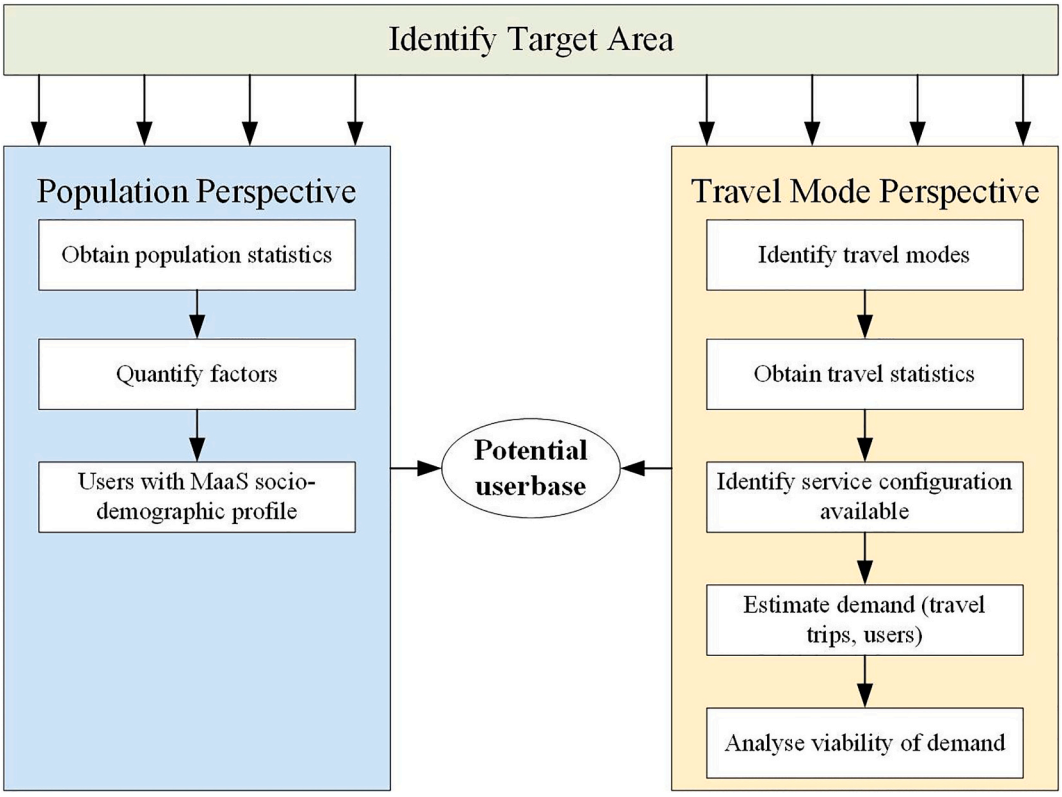

Fig. 3. Practical application of potential MaaS user framework.

further by analysing the travel mode perspective based only on the data from the users whose demographics match those of a typical MaaS user.

The practical application of the potential MaaS user framework has possible implications for future MaaS operators and transport planners. Potential MaaS operators can use the potential MaaS user framework to estimate the potential userbase of MaaS and the potential configurations of MaaS schemes. This could be for smaller MaaS operations, such as a corporate MaaS system, or for larger MaaS systems, such as for specific cities, provinces or countries. Furthermore, this research has implications from the supply-side dimension as well future public transport and building infrastructure planning. This planning can utilise the potential MaaS user framework to inform traffic management planning by considering MaaS service potential usage. Alternatively, insight is provided into redesigning current public transport to prepare for widespread MaaS adoption at provincial and national level.

It is important to note that factors from the population perspective may also influence factors from the travel mode perspective. Although the potential MaaS userbase could be described from either the population perspective or from the travel mode perspective, a complete view of the MaaS userbase is only possible if both perspectives are considered together. Overall, the potential MaaS user framework can be used as a tool to make quicker decisions regarding the possible MaaS userbase. The potential MaaS user framework builds on the previous frameworks in that it also focuses on travel choice factors but is used to gain insight into the potential MaaS userbase.

7. Contribution to scholarly knowledge

The aim of the research was to provide a framework to determine the potential MaaS userbase in a developing country using the characteristics of a typical MaaS user. The current MaaS knowledge base has a limited perspective how to estimate MaaS services adoption by the users. This research provides a framework that contributes to a better understanding of the potential userbase of MaaS from the population and the travel mode perspectives. Additionally, the framework integrates the developing countries travel modes configuration factors, which is a rare focus in scholarly knowledge. The practical value this framework is the ability for MaaS service operators to evaluate the viability of different transport modes.

Limitations exist such as the exclusion of external variables and other travel mode factors such as infrastructure requirements and driver behaviour. While a demand side approach was adopted in this paper it does present valuable information for the supply side as well, such as what the users want in their mode of travel. The potential MaaS user framework could be adapted to include more factors as needed and be further validated and tested with test cases in future studies.

Another limitation is that the characteristics of the typical MaaS user may be different from one country to another. The potential MaaS user framework can only be used to estimate the potential first adopters of MaaS, but does not show how MaaS can grow and expand into the excluded characteristics. Further research would involve using the potential MaaS user framework in case studies, which will allow for a comparison between the characteristics of the users from different areas. Further research could also include potential recommendations for a specific MaaS scheme based on the evaluated userbase and to include the growth of MaaS into the framework.

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.

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