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The Impacts of Mobility-as-a-Service (MaaS) on a Diverse Society: A Framework for Advanced Assessment

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Abstract

With the latest developments in transportation technologies and services, the concept of MaaS has spawned its way, where consumers can purchase access to different modes and services owned and operated by several mobility service providers through a single integrated digital platform. Nonetheless, the MaaS ecosystem and benefits have not been fully understood yet, which varies case by case depending on the communities' behavioral responses. Qatar is known as one of the countries with a highly diverse population where many expatriate workers come from different cultures. This necessitates a comprehensive mobility arrangement given their various travel needs and diaries. To contribute to a comprehensive analysis of MaaS impact while taking into consideration societies' diversities, this paper aims to develop a framework to assist in evaluating and assessing MaaS design alternatives and their impact on different population segments. This study was conducted by utilizing existing literature findings about MaaS assessment supported by a stated preference (SP) survey from a Qatar case study. We found that there are a limited number of key performance indicators (KPIs) to comprehensively evaluate MaaS social impacts and mobility network efficiency. Therefore, as part of the assessment framework, additional KPIs were introduced for comprehensively evaluating MaaS's direct impact on transport networks and broader implications for social equity, economy, and human well-being. MaaS KPIs should consider reporting by age, monthly income, and ethnic socio-demographic factors. This can serve as a useful guide for diverse communities, particularly in Qatar. Furthermore, outputs from the assessment framework can be used as inputs to evaluate impacts on the MaaS provider's profit-making and business prospects.

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1. Introduction

Mobility-as-a-Service (MaaS) is a relatively innovative concept in the transportation industry that has gained momentum in recent years [1-3]. One of the main advantages of MaaS is that it offers a unique and seamless interface to users, aggregating heterogeneous transport options offered by different mobility providers and handling the entire experience of traveling, from information provision to travel planning and payments [4-6]. Additionally, MaaS can take its users to the center of the offer and aims to portray a portfolio of multi-modal mobility services that achieve sustainable policy goals and objectives to its users [7]. Notwithstanding, there are concerns about how MaaS may impact mobility in society as it becomes more prevalent [2]. One concern is the possibility of customizing MaaS impacts on mobility. This refers to the consolidation of all mobility services in a single platform, bringing about market concentration [8]. This concentration may degrade competition ultimately and thus adversely impact smaller mobility providers and users with limited access to MaaS platforms or mobility services. Another concern is how MaaS may align with achieving higher-level goals i.e. equity, sustainability, and responsible innovation [9].

The adoption of MaaS as a framework for delivering multi-modal mobility services has the potential to impact society in a variety of ways significantly. Many studies [10-12] on MaaS discussed individual impacts. However, there were no discussions on the impact of the economic side of the users, the impact on the operators, or the well-being and social impacts of the MaaS system. According to [13], the assessment framework should also consider the possibilities of MaaS adapting its services as per the needs of each user, which could give rise to an increased private requirement for transport infrastructure if the levels of vehicle usage and occupancy are not improved. To address these concerns, it is necessary to have an assessment framework to analyze the impact of MaaS on vehicle usage. This comprehensive approach also ensures that the assessment framework for MaaS accounts for its consumers' behavior and in the long run broader societal impacts of MaaS.

A multi-level assessment approach was provided by the authors [14] and can be used to systematically evaluate the environmental, economic, and social effects of MaaS on individual, and societal levels. To illustrate such a framework, theoretical and hypothetical approaches are predominantly applied by examining generic MaaS service context [15]. Furthermore, the actual impact of sustainability is also not acknowledged even though many publications have made the assumption that MaaS may have good ecological benefits [16].

Qatar's population comprises 91.6% of non-nationals, primarily expatriates, and 8.6% of Qataris [17]. Implementing MaaS in countries such as Qatar with diverse societies, given their various forms of mobility needs and travel behaviours can be challenging. When it comes to employment and education, Qatar has achieved tremendous progress in supporting the rights of vulnerable and disadvantaged groups and integrating them into society over the past decade. It was also indicated that Qatar intends to develop an atmosphere that promotes the inclusion of the vulnerable and disadvantaged groups of the society and workforce, which increases community involvement to maintain social protection. Meanwhile, Qatar National Vision QNV 2030 encourages regional cooperation to solve the negative environmental effects of pollution [18].

Given the above-mentioned aims and scopes, MaaS could be a suitable mobility solution for Qatar, which may (1) reduce the number of passenger cars on roads and hence the environmental effects of pollution and (2) provide accessible and affordable transportation services to all types of user groups of the community. Consequently, this paper is to address the following research questions (RQs):

- 1) What are the impact areas and main KPIs to holistically assess the MaaS system and its impacts on the mobility and society?
- 2) How the KPIs are related to Sustainable Development Goals (SDGs) and various stakeholders?
- 3) How can an assessment framework of MaaS take demographic factors of social population groups of diverse society into consideration?

To achieve the above-mentioned goals, this study utilizes the findings of existing studies in the context of MaaS assessment. The study is supported by a recently conducted stated preference (SP) survey of MaaS market demand in Qatar. As part of this research, we identified KPIs to comprehensively evaluate the impacts of MaaS on travel behavior, public policy for sustainability, and transit service efficiency. Furthermore, the impacts of MaaS on various stakeholders and social population groups are investigated.

It is anticipated that such an assessment framework will pave the path to achieving the strategic goals i.e. sustainability, equitability, and social inclusion of MaaS which is aligned with those of policymakers and stakeholders in the State of Qatar. The structure of this paper is formed as follows: Section 2 documents the Methodology involved in the development of the MaaS appraisal framework, the literature review on KPIs studies, and the SP survey. Section 3 documents the analysis results. The impacts of policies on the MaaS assessment framework are presented in Section 4. Lastly, Section 5 concludes with recommendations, management implications and the way forward.

2. Methodology

2.1. Assessment Framework Development Principles

Basically, the intention of an assessment framework is to provide a structured and purpose-driven method for evaluating, measuring, or analyzing various aspects of interest. It serves as a valuable tool for decision-makers, regulators, educators, and organizations to achieve their goals, improve performance, and enhance accountability.

To provide a systematic approach for evaluating the impact of MaaS on society across different dimensions, developing an impact assessment framework is proposed [15]. Such a framework would aid policymakers and stakeholders in evaluating the impacts of MaaS on society as a whole through an evidence-based approach [9]. The aforementioned framework should be comprehensive, multi-dimensional, inclusive, accountable, participatory and transparent [15]. It should also reflect the needs and preferences of different groups of the society, be regularly updated to keep up with the changes in technology and needs of the society and incorporate high-level goals for equity, sustainability, and responsible innovation [19]. The evaluation framework should also take into account the supply-side features of a possible MaaS system and transportation network [20]. Moreover, it has to take behavioral impacts and the potential future contributions of MaaS to the transformation of mobility in the community into consideration.

Moreover, the evaluation approach should also consider changes in travel behavior, accessibility, and affordability following the implementation of a MaaS system. It is essential to consider the impact of MaaS on different segments of society, including disadvantaged and marginalized groups [21]. The MaaS assessment framework should be able to customize mobility services based on the needs of each user group category [13]. Moreover, the assessment framework should reflect the needs and preferences of different groups of society, including those who may not have access to or knowledge about MaaS. In conclusion, the assessment framework for MaaS shall be comprehensive and multi-dimensional taking into account both consumer behavior and broader societal impacts on sustainability goals, such as environmental impact and social equity, as well as the impact on the economy and urban/regional development [21], which can provide its impact on mobility and society in a broad range.

2.2. Performance Indicators and Impact Areas

Monitoring KPIs is a fundamental practice for business owners to evaluate performance, make informed decisions, and continuously improve their operations. It provides a data-driven approach to managing and growing a successful business. The selection of the critical MaaS performance indicators is a crucial phase in the design of the assessment framework. Following that, KPIs were categorized according to the level and magnitude of their impacts on travel behavior, transport network efficiency, and social, economic, and environmental impacts [22]. For instance, to measure the social impact of MaaS, metrics such as accessibility and affordability should be considered. Accessibility can be measured in terms of the availability and quality of MaaS services to different societal groups, including those with limited mobility options. Affordability can be evaluated by measuring the overall cost of MaaS services, including relative costs compared to those of other mobility options. Travel expense savings for consumers and service providers are relevant metrics here. To incorporate the economic impact of MaaS, metrics such as job creation and revenue generation need to be taken into the equation. On the other hand, environmental impacts can be investigated by for example measuring changes occurring in greenhouse gas (GHG) emissions, energy

consumption, and air quality metrics. A participatory approach to develop the MaaS assessment framework is recommended to integrate these metrics.

The impact of MaaS on travel behavior can be assessed through various metrics such as a change in the trip-making and its sequence, destination choice, transport mode, and departure time choice. Transportation network efficiency is an influential metric that reflects the effectiveness and success level of MaaS. This can be achieved by assessing factors such as travel time, delay, waiting time, and frequency of services.

In general, the methodology adopted in this study is based on (1) a systematic literature study and (2) utilizing the findings of a stated preference survey on the propensity of the people of Qatar toward using MaaS. Figure 1. Illustrates the methodology of this study.

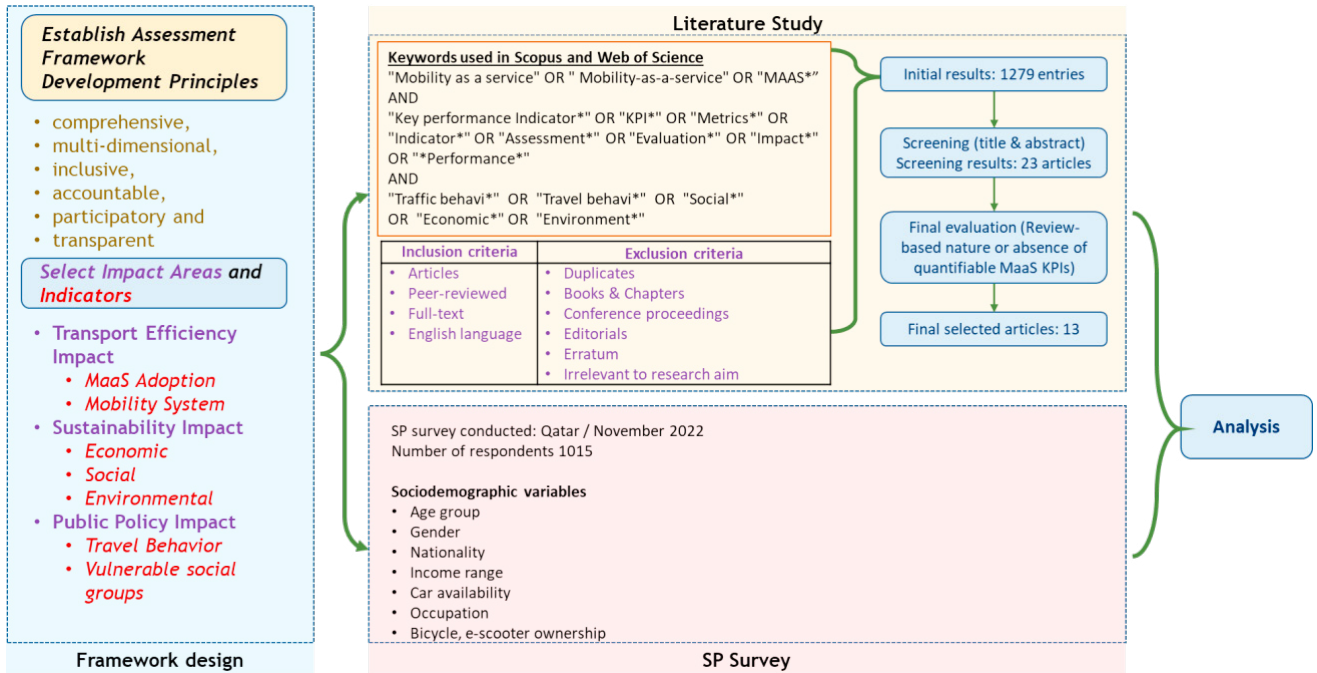


Fig. 1. Study Methodology

2.2.1. Literature Study

This research undertook a systematic literature review approach to select KPIs for studying MaaS. The review encompassed a comprehensive search across the Scopus and Web of Science databases, yielding a total of 1279 entries. Appendix A.1. represents the keywords used in the search. The inclusion and exclusion criteria were applied (are mentioned in Appendix A.2.), resulting in the refinement of the articles to 651. Further screening based on title and abstract led to the identification of 23 relevant papers. Subsequent evaluation eliminated 10 papers due to their review-based nature or the absence of quantifiable MaaS KPIs. Ultimately, a final set of 13 papers was determined as the basis for the selected KPIs. These papers were deemed suitable for the extraction and selection of KPIs for MaaS research. The selected KPIs encompass various aspects of MaaS performance, such as MaaS user adoption and engagement, Travel behavior changes and mobility efficiency, social acceptability and customer satisfaction, and sustainability.

2.2.2. SP Survey Study

The results of a stated preference survey undertaken in the fall of 2022 to evaluate the willingness of people of Qatar to use a MaaS system with 1015 respondents were utilized to provide insight and preliminary knowledge of how different MaaS packages were perceived by different population segments. The participants needed to compare varying and differentiated scenarios in terms of travel mode(s), the required number of rides, associated travel costs,

and sharing incentives. By analyzing the SP survey data the intention is to accommodate the social and cultural differences between social groups for devising the reported KPIs. Analyses were conducted to identify the key influencers in respondents' perception of MaaS subscriptions by incorporating the significance of sociodemographic variables such as gender, ethnicity, occupation, age, income, monthly income, and car and bicycle ownership into analyses and statistics. Figure 2 illustrates some of the descriptive analysis for the sociodemographic variables from the SP survey.

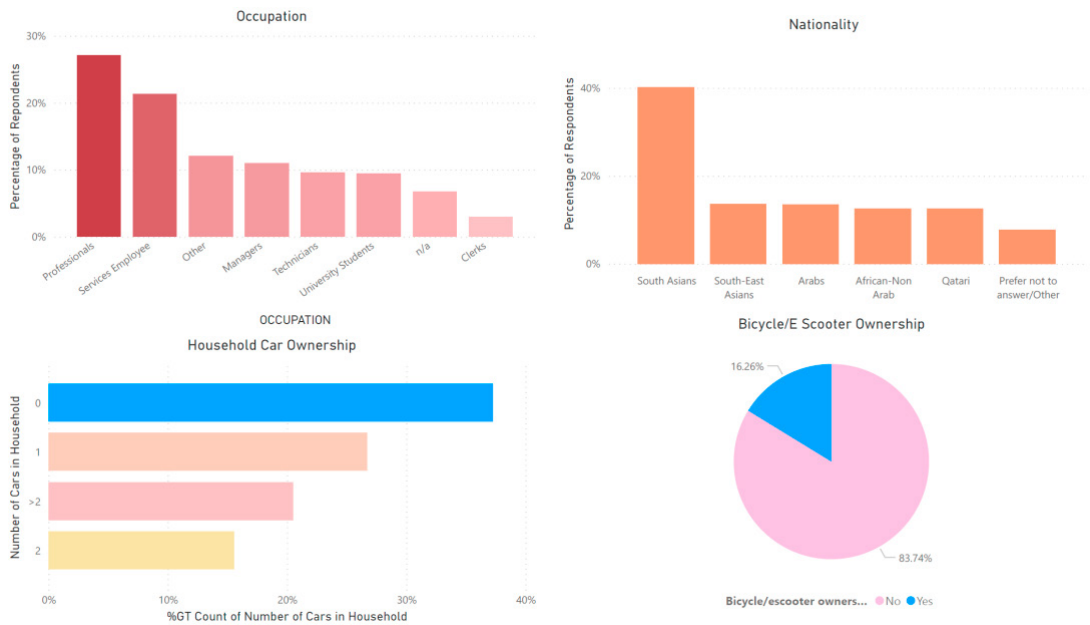


Fig. 2. Examples of Descriptive analysis for the Sociodemographic Variables from the SP survey

3. Analysis

3.1. KPIs for MaaS Assessment Framework

Based on the articles shortlisted from the systematic review, 32 KPIs were retrieved and analyzed considering the impact area, and relevance to SDG as illustrated in Appendix B. The retrieved KPIs within these studies were focused on measuring MaaS adoption and user acceptance. There are several studies and KPIs defined to measure user behavior changes in terms of changes in transport mode use, trip chain and sequence, trip destination, route choice, and departure time choice. However, there are very limited KPIs to report the impacts of MaaS on mobility network efficiency. Such impacts may refer to, for example delay, travel time, congestion index, and travel time index [23-25]. In the same way, KPIs to measure impacts on public transit such as ridership, travel time, service frequency, punctuality, and reliability shall also be included in the assessment framework. It is noticed that scarcely KPIs report sustainability and if that is the case, they were mainly to report on the impacts of MaaS on air quality i.e. GHG emissions. Hence, it is recommended to add KPIs within the assessment framework to incorporate social and economic sustainability to the general public and community. For instance, KPIs such as accessibility and affordability in particular for vulnerable population groups such as elderly people, single mothers, students and low-income population groups, and business development [26, 27] could be included in the assessment framework to comprehensively evaluate MaaS's social impacts. Other KPIs such as productivity, promoting the use of renewable energy, revenue generation and its impact on the country's GDP, and average travel cost saving shall be considered to evaluate economic impact as well [15, 28-30]. Inclusion of Population Social Groups into MaaS Assessment

It should be noted that the descriptive analysis of the survey compared to Qatar's population indicates that the results are not biased and thus are indicative of the national population. For example, the gender distribution of the

sample is 69% males and 31% females. It is indeed very similar to the gender split from the national Census data [31]. For 89% of the respondents, a passenger car is available, either as a driver or as a passenger and this reinforces the fact that Qatar is a car-centric country. In terms of nationality, 40% of the respondents were South Asians, which is a true representative of the national population. It is also to be noted that majority of the respondents do not own a bicycle or an e-scooter which indicates the reluctance to use active transportation modes.

Table 1 presents the significant factors at the 95% level of confidence for socio-demographic factors of respondents who had presented their preference for MaaS subscription. It can be noticed that traveler's age, monthly income level, occupation, and ethnicity significantly impacts the preferences toward modes within MaaS subscription. It can also be noticed that gender, car and e-scooter ownership, and marital status were found to be insignificant factors for choosing modes within the MaaS subscription. However, monthly income and occupation are highly correlated. Therefore, MaaS KPIs shall consider reporting these KPIs by age, monthly income, and ethnicity.

Table 1. Significance of socio-demographic factors in respondents' preferences for MaaS subscription by travel mode

Socio-demographic Factors	Population Social Group	Modes within MaaS Subscription			
		Public Bus	Metro	Taxi	Ride Sharing
Gender	Male, Female	NS	NS	NS	NS
Age (Years)	18-29, 30-39, 40-49, 50-59, >60	NS	NS	Sig	NS
Monthly Income (QAR)	0-4999, 5000-9999, 10000-19999, 20000-39999, >40000	Sig	NS	NS	NS
Occupation	Full-time work/student, Managers, Professionals, Technicians/Clerks, Services employees, University Students	NS	Sig	Sig	NS
Ethnicity	South Asians, South-East Asians, African-Non Arab, Qatari, Arabs	NS	Sig	NS	NS
Household Car Ownership	0, 1, 2, +2	NS	NS	NS	NS
Bicycle/E-scooter Ownership	NO, YES	NS	NS	NS	NS
Marital Status	Single/Widower/Divorced, Married w/wo children (Family lives in Qatar)	NS	NS	NS	NS

NS: Not Significant at 95% confidence level

Sig: Significant at 95% confidence level

4. MaaS Inclusiveness for Diverse Communities: Challenges and Opportunities

As MaaS continues to expand and impact the transportation landscape, it is crucial to consider its impacts on diverse communities. There is a concern that MaaS may exacerbate existing disparities in access to transportation, particularly for those living in economically disadvantaged or geographically isolated communities who may not have access to the necessary digital infrastructure for using/ subscribing a MaaS platform. There is always a risk that MaaS may not cater to the specific needs and preferences of diverse communities, such as older adults, people with disabilities and reduced mobility, as well as non-native speakers with varying levels of proficiency in the language in which the MaaS platform operates. Nevertheless, there are proposed frameworks and policy recommendations to assess the inclusion of such vulnerable social groups into MaaS services [26]. The recommendations of the same study can significantly aid in assisting stakeholders and policymakers in developing MaaS services targeted at sustainable and inclusive transportation that is accessible to all types of users.

Several opportunities, as well as challenges, must be considered to address the above-mentioned potential concerns to ensure that MaaS is inclusive for diverse communities. For instance, an opportunity to enhance inclusiveness is to provide affordable and efficient transportation options, particularly in areas with limited availability of public transit infrastructure. In Qatar, first and last-mile solutions are unavailable for people living in rural areas since public transit services are not available. Furthermore, demand-responsive services with access to bus stops and metro stations are not easily available. Such a deficiency can limit the use of MaaS for people who live in remote and underdeveloped areas, particularly for people who are after affordable transportation means.

Hence, in developing MaaS, features such as offering personalized and on-demand options to such communities should be considered. Beyond the KPIs discussed in the previous sections, MaaS providers need to develop technologies and services that cater to the needs of various user groups i.e. MaaS application languages, subscription-offered rides and associated costs to suit low-income migrants in order to ensure that MaaS is accessible and beneficial to diverse communities. Meanwhile, MaaS application should be capable to offer simplified user interfaces to overcome potential barriers associated with language and digital literacy or vision impairments for people with poor literacy, and disabilities, as well as older adults.

As indicated before, the design of a MaaS platform should accommodate the needs of low-income communities who might not have access to private means of transportation. To achieve such a goal, MaaS providers must work closely with local governments and community organizations to identify the specific needs of diverse communities and incorporate them into the design and implementation of MaaS initiatives.

5. Conclusion

In summary, the assessment framework for evaluating MaaS impacts on a diverse society should consider sustainability and responsible innovation, user experience and interface, data privacy and security. Moreover, the appraisal framework should be used to develop MaaS initiatives tailored to fulfill local needs and aspirations while aligning with broader sustainability objectives. Overall, implementing MaaS initiatives presents a unique opportunity for policymakers and service providers to transform people's mobility and travel patterns within and across cities in an environmentally friendly and socially inclusive manner. Hence, it is important to consider a holistic and inclusive approach in MaaS development to enhance its market penetration rate within the general public, in particular, in countries such as Qatar with a remarkably high rate of expatriates coming from diverse cultures.

It is observed that there are insufficient KPIs for measuring the effectiveness of MaaS from the mobility perspective as well as societal implications. In this study, additional KPIs were proposed and related to the SDGs in order to fully assess the immediate impact of MaaS on transportation networks as well as its wider implications on social, economy, and human well-being. Following the analysis of the significance of socio-demographic factors in respondents' preferences for MaaS subscription by travel mode, it was found that MaaS KPIs shall consider reporting these KPIs by age, monthly income, and ethnicity.

In the context of management implication, the assessment framework presented here can be seen as an instrument in ensuring that MaaS initiatives are successfully implemented in an innovative manner that prioritizes sustainability and societal inclusion responsibly. The recommendations made above are essential in ensuring the success of MaaS initiatives, as they consider the diverse needs and aspirations of various segments of society while ensuring that MaaS initiatives are aligned with broader sustainability and equity goals. Furthermore, the appraisal framework developed for analyzing the impacts of supply-side characteristics of a potential MaaS scheme on the transport network can be used by policymakers to design MaaS initiatives that are tailored to the unique needs of diverse communities, and in line with sustainability objectives at the local as well as regional levels. To further enhance the effectiveness of the assessment framework, further studies should be done by focusing on the identification of appropriate measurements for appraising the sustainability impacts of MaaS initiatives in the long run.

This study considered predominant or common socio-demographic factors when analyzing users' preferences of modes within MaaS subscriptions based on available data extracted from a stated preference survey conducted in Qatar in the 4th quarter of 2022. As the way forward, more research will be conducted to consider a wider range of socio-demographic attributes which is the case for other countries in the Middle East region.

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