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Mobility as a Service: A Review on Recent development and future envision

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ABSTRACT

Mobility as a Service (MaaS) is an innovative transport concept, anticipated to provide travelers with different kinds of travel services, more sustainable than a private car, in a simpler, packaged way. It combines different transport modes to offer a tailored mobility package, like a monthly mobile phone contract. The rapid development of intelligent transportation system and the shared economy has speeded up the development of MaaS in these years. In this paper, we aim at classifying the existing research on MaaS and the characteristics of MaaS into different categories, in order to answer the following questions after reviewing the existing literature: What is MaaS? Who are the main actors in MaaS? How can MaaS be implemented? Why should it be implemented? Where will MaaS end up in this wave of disruption? When we talk about MaaS, what are we focusing on? What is the future leading frequency of MaaS? Finally, based on the existing literature, we envision the leading future of MaaS.

INTRODUCTION

Mobility as a Service (MaaS) is a very recent mobility concept. It can be thought of as a concept (a new idea for conceiving mobility), a phenomenon (occurring with the emergence of new behaviors and technologies) or as a new transport solution. Hietanen (2014) proposed the first comprehensive definition of MaaS and described MaaS as a mobility distribution model that deliver users' transport needs through a single interface of a service provider. Demographia 2016 adds to this definition, by emphasizing the similarity with the telecommunication sector. Being based on the same definition, Finger, Bert, and Kupfer (2015) envisioned MaaS to integrate transport modes through the internet.
In recent years, the increasing number of transport services offered in cities and the advancements in technology and ITS have introduced an innovative Mobility as a Service (MaaS) concept. It combines different transport modes to offer a tailored mobility package, such as trip planning, reservation, and payments, through a single interface (Hietanen 2014). This bundling of mobility modes presents a shift away from the existing ownership-based transport system toward an access-based one. It offers users a tailored hyper-convenient mobility solution, with a promising perspective to substitute private car. Xi, H., et al (2020) indicated that Mobility-as-a-Service (MaaS) is an innovative paradigm in which continuous and unified mobility resources integrated from both public and private multi-modal transportation providers can be effectively and efficiently allocated

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to travelers based on their preference and willingness to pay (WTP) through a single payment on a digital platform (Haoning Xi et al. 2021).

Among the various solutions for coping with such increased mobility, Mobility as a Service (MaaS) stands out in two ways. First, MaaS has the inherent potential to decrease the use of private cars. Second, from the societal point of view, this kind of service would contribute to the societal goals of reducing the number of private cars in the city, an increase in the use of shared resources, a reduction in environmental impacts of transportation (Jittrapirom et al. 2018) .

The customers must not have too far to go to access a car, particularly for encumbered trips with children or shopping. This is a prerequisite for customers to be able to manage without a private car and is thus a decisive factor if the customer base is to expand, particularly outside the inner city. Service providers are expected to offer travelers easy, flexible, reliable, price-worthy and sustainable everyday travel, including public transport, car-sharing, car leasing and road use.

When requesting a complex service in a platform, each user must reveal information about his destination willingness to pay filtering based on total travel time, reliability (e.g. waiting time, the distance to boarding location and detour time), and comfortable degree (e.g. the number of co-riders) , thus a request is mapped to the set of feasible services offered by the Maas provider, a user will choose the one with the utility-maximizing service.

Given its promising prospects, there is still a high degree of ambiguity surrounding the concept with multiple sources varying to offer definitions of MaaS, many of which may conflict with one another or deal with different aspects of the concept altogether. Additionally, although several MaaS schemes have been implemented around the world, there is a lack of assessment framework that classifies their unique characteristics in a systematic manner. We argue that the mobility service should provide more continuous options which are the most significant factors for a traveler while planning his/her trip, such as total travel time, reliability (e.g. waiting time, the distance to boarding location and detour time), and comfortable degree (e.g. the number of co-riders, the number of transfer among different modes), instead of simple mode choice options emphasized in most of the existing literatures and schemes. In order to fill in these research gaps, we will design the mechanism for mobility service to determine the optimal price for both consumers and providers.

Matyas and Kamargianni (2019) emphasized the role of subscription in MaaS, giving the user the possibility to plan his/her journey, in terms of booking and paying the several transport modes that might be required, all in one service. To access the service, travelers will be asked to register or make an account. At a first level, this is to make booking and payment easier, as the concept envisions a 'seamless' com bination of all transportation modes and a 'Mobility Aggregator' that gathers and sells all services through a single smartphone app, allowing easy fare payment and one-stop billing Goodall et al. (2017). Based on the traveler's needs, he/she can have the choice of 'pay-as-you-go' or pre/post pay, considering his/her registration and a monthly subscription. At a second stage, subscription results in personalization, framing mobility services around traveler's preferences, which is one important advantage that is absent from conventional public transport services and thus not covering passenger's needs which might result in inconvenience (Atasoy et al. 2015). More specifically, tailoring the bundles to the heterogeneous needs of the subscribers (i.e. preferences in mode choice) is beneficial for both users and transport providers usually referred to as collaborative customization or personalization ((Sochor, Karlsson, and Strömberg 2016; Matyas and Kamargianni 2019a). In addition to the definitions above, which emphasize the bundling and subscription aspects of MaaS, there are various other interpretations of the term that underscore other aspects. Datson (2016) defines MaaS as a new way to provide transport, which facilitates the users to get from A to B by combining available mobility options and presenting them in a completely integrated manner. Thus, it is possible to consider MaaS as mobility service that is flexible, personalized and on-demand. Evidently, MaaS essential characteristic is the user-centric vision which frames the mobility service provision.

The key function of the internet and, more in general, of the technologies, has also been underlined in several definitions. NEMTANU et al. (2016) considered the Information and Communication Technologies (ICTs) as the main component of MaaS systems. They mention the collection, transmission, process, and presentation of the information necessary for identifying the best transport solution for user's needs. ICTs also play a vital part in information integration and convergence between users, providers, and services. The emergent notion in the Internet of Things (IoT), which further accentuate the connectivity between physical objects and virtual data, is a vision of Smart transportation systems to support the Smart City vision (Expósito-Izquierdo, Expósito-Márquez, and Brito-Santana 2017). In the context of MaaS, similar emphasis stressing the importance of integrations between transport data, data infrastructure and physical transport infrastructure can also be observed (Hietanen 2014).

By providing seamless travels with accessible and affordable solutions, MaaS has a pers

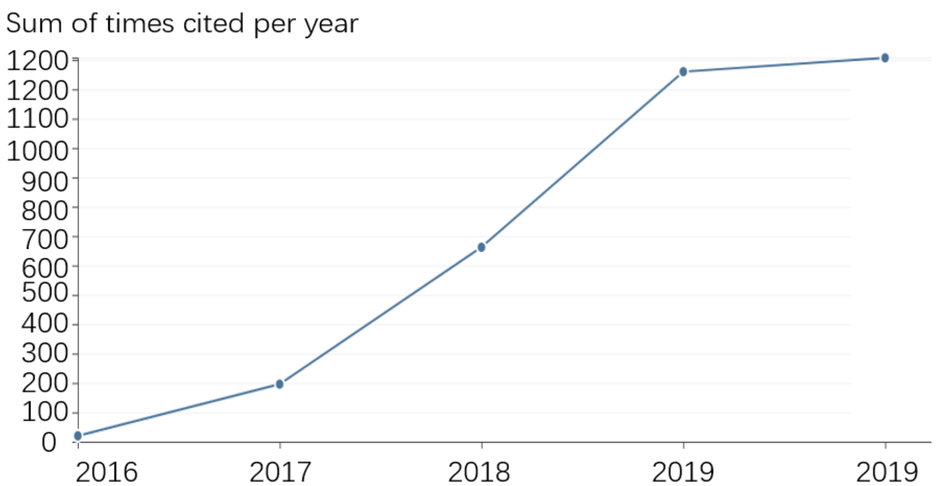

Figure 1. Google scholar results for searching the term "Mobility as a service"

pective to contribute toward the strategic goals to achieve integrated multimodal systems, substituting private vehicles with alternative models (Singh 2020; Matyas and Kamargianni 2019a; Hietanen 2014). Gould, Wehrmeyer, and Leach (2015) envisioned MaaS as an opportunity to decarbonize transport sector by reducing the use of private cars and encouraging the diffusion of electric vehicles (EVs) within the city. Integrating transportation in a service like MaaS can shift the interest from private car usage to alternative modes counteracting the negative effect of current transport systems on urban contexts and the environment. However, Polydoropoulou et al. (2020) pointed out the importance in setting MaaS tariff to ensure users' positive preference toward more sustainable modes, thus contributing to the sustainability vision. Interestingly, (Giesecke, Surakka, and Hakonen 2016) conceptualized MaaS as a socio-technical phenomenon with sustainability as a critical aspect, thus shedding the light on the sociological level and the sustainability dimensions of the concept. This highlights the importance of users' acceptance and adoption to MaaS, as well as its roles to transform their habits and behaviors to meet their travel needs in a sustainable way.

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Accordingly, other authors consider sustainability and user perspective as the core elements of MaaS concept.

As is shown in Figure 1, the search of Mobility as a service increased exponentially, which indicates that this is a recent concept and is becoming more and more popular.

CLASSIFICATION OF MAAS LITERATURES

The existing literatures related to MaaS can be divided into 6 types:

1) **MaaS ecosystem.** The first type of literatures focused on the MaaS ecosystem. From the perspective of the users, Pangbourne et al. (2020) considered the implementation process of MaaS and the impacts of implementation on urban governance and analyzed the social impacts of MaaS to obtain series of unintentional social influences. claimed that the externality of congestion should be considered through pricing the scarce road Spaces in the MaaS biological system, which is crucial to the preservation of MaaS in sustainable environment. Referring to the formula of power industry, Kamargianni and Matyas (2017) established a new mobility model that aims to bridge the gap between public and private transport operators on a city, intercity and national level, and envisages the integration of the currently fragmented tools and services a traveler needs to conduct a trip (planning, booking, access to real time information, payment and ticketing).

2) **Bundling services of MaaS.** The second type of literatures focus on the bundling services of MaaS. Despite the different definitions of MaaS, it is clear that MaaS are multi-modal packages supported by the same integrated payment platform. Ho, Mulley, and Hensher (2020) conducted stated preference (SP) selection tests in Sydney, Australia, and Tyneside, UK, respectively, and compared the similarities and differences of different MaaS packages. This results could be translated into a decision support system (DSS) that would allow the assessment of market potential of MaaS based on the willingness to pay (WTP) of users. Guidon et al. (2020) found that the value of offering public transit, ride sharing and parking bundling services as part of a combined service was much higher. It is concluded that combining all of the mobility modes into a single package might not be the best strategy, however, the best strategy could be obtained by bundling the modes with higher willingness to pay (WTP) and paying as you go for the modes with lower WTP.

3) **Suppliers of MaaS.** The third type of literatures focus on the suppliers of MaaS. Polydoropoulou et al. (2020) proposed a qualitative method for identifying the basis of a business model that allows operators to create, exchange and capture value. The major participants include the operational service providers, the public communications sector and the regional administrative sector, the institutional factors will bring greater risk to the implementation of MaaS. A better coordination between the main body and the conductor is the key push force of the MaaS. Smith, Sochor, and Karlsson (2020) examined the role of MaaS exchange platform (IMI) - the platform between the operator and the operator of MaaS. This paper introduces a case study of a failed MaaS platform in Sweden, through which the valuation and claims of MaaS are explored. The results indicate that the implementation of the

MaaS exchange platform should ensure that the power of MaaS is not limited to technical services, but also include customized services for individual participants. MaaS platform should have clear and definite objectives to ensure mutual understanding and trust among multiple participants. MaaS service can only be successful if it is stimulated and matched by respective policies. From the perspective of business pattern, knowing more about the participants can promote the successful implementation of MaaS.

4) **Pilot projects of MaaS.** The fourth type of literatures introduce the results of the pilot projects for MaaS in different countries. At present, there are few MaaS projects operating in large scale. Recognizing the challenges of cooperation among different mobility providers, Meurs et al. (2020) studied the potential for mobility suppliers to form alliances as a pilot for MaaS. Despite common goals, risk control and trust building are still important for alliance formation. The results show that the information and knowledge interaction between suppliers is particularly important. MaaS is often discussed in the urban scene. Wright, Nelson, and Cottrill (2020) discussed the transformation of MaaS in the rural area and regarded MaaS as the combination of the two modes of car-pooling and public transit. It is showed that about 20 % of combinations are bundles of carpooling and public transit based on a mobility software. This indicates that introducing carpooling in the bundles can enhance the attraction of MaaS in the suburban area. Singh (2020) introduced MaaS in developing countries such as India and explored the most recent example in Kochi for multi-modal communication and integration. The research points out that the failure of MaaS has prompted the implementation of new policies. In Kochi, a series of series of results were derived, including the improvement of transport sectors, inclusion of different operation participants, and more effective management system. In summary, these pilot projects provide us with answers to some of the questions needed to be considered in the deployment of MaaS. Understanding the results of these different pilots will provide stakeholders with insights on the large-scale implementation of MaaS. Wright, Nelson, and Cottrill (2020) introduced a new journey planning App (known as RideMyRoute) that allows users to discover and make connected journeys involving carpooling and public transport, presenting key aspects of its design, development and testing. Results from a trial of the RideMyRoute App in four European test sites (Canton Ticino, Brussels, Zagreb and Ljubljana) revealed that the App was able to suggest trip planning solutions which included carpool options for one in five journey planning solutions and that the majority of these were solutions that involved connection from carpool to public transport.

5) **Simulations of MaaS.** The fifth type of literatures conducted the simulation on MaaS. Becker et al. (2020) constructed large scale MaaS simulations in Switzerland and provided the results for the mass transport system. As is expected, the sharing mobility consist of ridesharing and bicycle sharing is more popular in improving the operational efficiency of the system and reducing the energy consumption. The simulation results show that the mobility efficiency can be improved in suburbs if this shared mobility substitute public transit services. The key link in multi-mode door to door travel is the last mile. Franco, Johnston, and McCormick (2020) used the aggregated mobile phone network data to generate travel demand of the last mile. The model indicates when and where to place the new services for demand response transit service and quantify the benefits of public transport and reduction in the use of private cars, which will provide the basis for the public sector. López and Lozano (2020) built a multi-mode hypergraph model for integrating real-time information under the multi-mode to provide technical support

for MaaS path planning.

6) **Problems and challenges of MaaS.** The sixth type of literatures are related to the problems and challenges that MaaS face. A discussion on the design and implementation of MaaS can be completed only if these challenges are resolved. Merkert, Bushell, and Beck (2020) identified the importance of system integration and the elimination of the influence on completion boundary among different modes in the system. The public and private combined operation of the MaaS system will bring more competitive pressure to the operators, and also bring great challenges to the multi-mode seamless operation of MaaS. They proposed that Software-as-a-Service (SaaS) can be extended with governance and operational processes that enhance their ability to facilitate Collaboration-as-a-Service (CaaS) to offer a reimagined MaaS2.0 = CaaS + SaaS. Rather than using the traditional MaaS broker, CaaS incorporates operators more fully and utilizes their commercial self-interest to deliver commercially viable and attractive integrated public transport solutions to consumers. They indicated that MaaS should learn how to construct the frame of cooperation and competition from the aviation field. Karlsson et al. (2020) developed a framework, with a basis in institutional theory and the postulation that formal as well informal factors on different analytical levels (macro, meso and micro) must be considered. The research was organized as a multiple case study in Finland and Sweden and a qualitative approach was chosen for data collection and analysis. A number of factors with a claimed impact on the development and implementation of MaaS was revealed. At the macro level, these factors included legislation concerning transport, innovation and public administration, and the presence (or not) of a shared vision for MaaS. At the meso level, (the lack of) appropriate business models, cultures of collaboration, and assumed roles and responsibilities within the MaaS ecosystem were identified as significant factors. At the micro level, people's attitudes and habits were recognized as important factors to be considered. Schikofsky, Dannewald, and Kowald (2020) established the partial least squares structural equation model based on the theory of consumer behavior and technology acceptance model to understand the motive of potential users of MaaS. Simulation Result point out that the potential factors of MaaS users, including user's subjective initiative, efficiency advantage and potential hedonistic motivation. These papers provide insights into the further development of tractable models for us, helping to expand the implementation of MaaS from pilot to comprehensive promotion and implementation.

CHARACTERS OF MAAS

According to the existing literatures, Table 1 summarizes the main characteristics of MaaS.

Table 1. main characteristics of MaaS

	Focus	Description	Literature
1	Bundles	Encourage the use of public transport services, by bringing together multi-modal transportation	(Ambrosino et al. 2016; Wright, Nelson, and Cottrill 2020); Hoadley 2017; Matyas and Kamargianni 2019)
2	Option	MaaS platform offers users two types of tariffs in accessing its mobility services: "mobility package" and "pay-as-you-go".	(Wong, Hensher, and Mulley 2020; Ho et al. 2018; Fioreze, de Gruijter, and Geurs 2019; MaaS Alliance 2018; Zhu, J. et al., 2019)

3	Platform	MaaS relies on a digital platform through which the end-users can access to all the necessary services for their trips.	(Barreto, Amaral, and Baltazar 2018; Wong, Hensher, and Mulley 2017; Hein et al. 2018; Bendel et al. 2013; Wong, Hensher, and Mulley 2017; Smith, Sochor, and Karlsson 2019; H. Xi and Zhang 2018a; Zhu, J. et al. 2019; Duan, Y., & Feng, 2019.)
4	Ecosystem	MaaS ecosystem is built on interactions between different groups of actors through a digital platform: customer, a supplier of transport services.	(Kamargianni and Matyas. 2017; Becker et al. 2020; Polydoropoulou et al. 2020; Smith, Sochor, and Karlsson 2019; Pangbourne et al. 2020; Hensher 2017)
5	Technologies	Different technologies are combined to enable MaaS: devices, such as mobile computers and smartphones; a reliable mobile internet network	(Wong, Hensher, and Mulley 2017; Li and Voege 2017; Callegati et al. 2017; L. He, Xi, and Qiu 2019; H. Xi and Zhang 2018a; Liu He et al. 2020 Hu et al. 2016; Lu, W et al, 2020; Wang, Z. et al. 2020; Yu, Y. et al. 2020; Wang, Z. et al. 2020; Zhu, J. et al. 2019)
6	Demand orientation	MaaS is a user-centric paradigm. It offers a transport solution from customer's perspective to be made via multimodal trip planning feature.	(Mulley, Nelson, and Wright 2018; Vazifeh et al. 2018; Azevedo et al. 2016; Zhang, Rossi, and Pavone 2016; Wen, Nassir, and Zhao 2019)
7	Customization	Customization enables end users to modify the offered service option in according to their preferences.	(Lyons, Hammond, and Mackay 2019; Ho et al. 2018; Sochor, Karlsson, and Strömberg 2016)
8	Sustainability	MaaS can is environmentally friendly and can incentive travelers to use public transit and decrease environmental impacts	(Signorile, Larosa, and Spiru 2018; Haoning Xi et al. 2020; Haoning Xi and Zhang 2018; H.-N. Xi et al. 2018; L. He, Xi, and Qiu 2019; H. Xi and Zhang 2018b; Liu et al. 2017)

FUTURE OF MAAS

Wong, Hensher, and Mulley (2020) proposed the concept of modal efficiency illustrated through a conceptual framework situating both existing and emerging modes of transport around spatial and temporal dimensions. This framework helps us evaluate how the push towards smaller and more flexible transport services

Autonomous and connected vehicles revolutionize the mobility by allowing machines to take over driving that for over a century has been exclusively a human activity, while electrical vehicles are already helping decarbonizing the transport sector. An important trend that made the MaaS concept suddenly popular and acceptable now is that this perspective of seeing "everything as a service" fits squarely with the emergence of sharing economy where people value experience over possession of material goods or products. This global economic transition from a focus on "products" to "experience" is significantly changing the way firms produce, sell, market, and deliver goods or services to their customers. Furthermore, it is important to recognize that the increasing support for experience and sharing economy was made possible through the technological breakthrough in virtual reality, internet of things, and intelligent systems built on big data and machine learning, that accelerates the proliferation of cyber-physical systems where the boundary between physical infrastructure and digital platform is blurry. With the recent breakthrough in software and mobile technology, digital platforms can be integrated with physical systems to provide mobility services (e.g. Uber and Lyft), retail services (e.g. Amazon and eBay) and content and entertainment services (e.g. YouTube and Netflix), without being subject to geographical boundaries or distribution networks (Andy Hong, 2019.).

CONCLUSION AND DISCUSSIONS

Mobility as a service (MaaS) is about determining what people are willing to pay based on what level of mobility, the operators who merge the mobility as a service, the profitability is about the government designing a platform so that the public are emerged and public get served. reliability, average travel time. Mobility as a service should be taken literally as a service, the bigger microeconomic trend is the depth of products, products are being replaced by services, what is the market equilibrium implication about? The long-term equilibration means if we live from each origin to same destination at the same time, but if you pay $ 5, and I pay $ 4, you get higher utility. What is utility? Travel time, reliability, comfort, the long-term trend would be the continuous pricing and continuous mobility, and the exact example is Amazon cluster, when we are about using it, it's just there. You pay exactly depend on what you want. (computing service). Mobility as a service is the same. You don't even get a car; you get a system. So price is into space, temporal, trajectory based on what you pay, that would be one way to achieve continuous pricing with continuous level of mobility, by imaging what the market equilibrium state is, there would be lots of methodologies and models come up to show what is the continuous pricing, and continuous service to understand what people's real utility for mobility and how they might trade-off between travel time and price, the first step is to do the interesting combinations, different outcomes if you pay different prices.

The best way for us to evaluate the pending development of MaaS is to consider the obstacles facing them. In this case, the five key factors are: (1) Obstacles to the driving mechanism; (2) Bottleneck of technology implementations; (3) Barriers to the travel ecosystem; (4) Obstacles to the new technology; (5) Business model barriers. These obstacles will have different impacts in evaluating the future role of MaaS. The greater the impact range of these obstacles, the more likely the potential users will remain the traditional mobility. It is important to understand the elements that facilitate the transformation of travelers and how MaaS may operate in the future. Current and future trends in transportation, including connected cars, autonomous vehicles, electric vehicles, Internet of things, will only help strengthen the concept of MaaS, rather than obfuscating it. Again, the global economic transition from products to experience and the growing blurriness between physical system and digital platform is what, I believe, is driving this transformation from transportation as an infrastructure/manufacturing focused industry to a more experience and value focused industry, allowing non-traditional companies, like Apple and Google, to have a competitive advantage over more traditional car manufacturers and civil engineering firms.

Due to the current development and the shift in economic structure and technological advancement, specifically, the shift from products to experience, and from hardware to software, it can be predicted that the one who can establish the most efficient and cost-effective cyber-physical platform enabling users to match physical systems with digital services and providing users with seamless connections to a wide range of mobility services will eventually take over and lead the future of MaaS, or even the transportation industry at macro level. And that's the reason why we envision the future of mobility and transportation industry will likely come from software and IT companies, not from civil engineering companies.

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