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Understanding Mobility as a Service: A Literature Review

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ABSTRACT

Urbanization is a rapidly growing process for cities and it naturally increases the supply/demand ratio of citizens or businesses. Thus, managing the transportation component of urbanization becoming more complex and enhancing or shifting the current infrastructure does not contribute to the solution. With the development of new technologies and alteration of user behaviors, mobility solutions should also adapt to satisfy the needs. "Mobility as a Service (MaaS)" is an innovative accessibility-based concept that combines multi-modal transportation enabling the user to choose and manage their trips in a single mobile app or web interface. The concept is based on spatial analyses -mainly network analyses-, digitalization, and management of discrete mobility systems. It offers a manageable and sustainable mobility service by maximizing the benefits of the current infrastructure. MaaS ecosystem builds relations between users and different stakeholders such as public or private transport suppliers and municipal governments in a single platform and it offers personalization and customization for both sides. In this paper, MaaS is examined on the conceptual level based on the literature and existing implementations.

1. INTRODUCTION

The urban density of cities continues to increase and populous cities struggle to keep their transportation infrastructure active despite the increase. Strengthening existing infrastructure by adding new roads/connections or supporting different travel modes has contributed to the mobility of people and goods in the past. However, in today's conditions, such management of mobility is socially, environmentally, and economically insufficient. Reshaping the current roads or expanding the infrastructure is slow, costly, and non-ecologic way to solve the problem. Also, people no longer see the paradigm as a "more roads or more transit" choice, they tend to live in less vehicle-centric and sustainable cities (Goodall et al., 2017).

Technological advances enable different transportation modes (public transport, car-sharing, e-bikes, etc.) to be managed and used more efficiently. Nowadays, ICT solutions intertwined with mobile phones are widely used for different transportation modes such as cab services (Uber, Lyft, Bitaksi), car-sharing (Car2Go, DriveNow, blablacar), and micro-mobility devices (Isbike, Martı). These services eliminate intermediates by making the matchmaking between customers and entrepreneurs in a mobile app platform (Giesecke et al., 2016). Although these services have advantages on user-centric mobility individually, they are mostly service-based commercial apps and do not offer an all-in-one solution or a mobility management platform for users or authorities. In such approaches, different transportation modes and their payment systems are presented to the user as different services and travel modes such as public transportation are generally not evaluated. Thus, it does not solve the problem of the number of vehicles in traffic and this leads to an ownership-based transport system rather than an access-based one.

"Mobility as a Service (MaaS)" is described as a user-centric, personalized, door-to-door travel management platform that digitally unifies trip creation, payment, and delivery processes across all transportation modes (Ho et al., 2018). It is an emerging smart technology that combines multi-modal transportation while enabling the user to choose and manage their trips in a single mobile application. The increasing number of transportation modes emerging through technological developments could be examined, operated, and managed in an

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integrated system by using the concept of MaaS. Its ecosystem builds relations between users and different stakeholders such as public or private transport suppliers and municipal governments in a single platform and it offers personalization and customization for both sides. As a concept, MaaS redefines the interoperability of transportation modes by supplying point-based access (door-to-door) rather than any type of stop-based access.

2. BACKGROUND

Digitalization and technological developments change people's behavior in mobility as in every field. Rising energy and private auto ownership costs, increasing congestion and greenhouse gas emissions, and ease of technological developments lead to shared mobility services around the world (Shaheen and Cohen, 2013). Shared mobility services provide the user with short-term access to shared private vehicles according to the user's needs (Shaheen, Cohen and Zohdy, 2016). Carsharing is the mainstream shared mobility system, however, the concept has been expanded to different transport modes such as bike-sharing, moto-sharing, and scooter-sharing (Shaheen and Cohen, 2013; Aries-Molinares and García-Palomares, 2020). This mobility shift has encouraged new mobility business models that are managed and operated through mobile applications and are embedded with technology. However, from the user's perspective, it becomes difficult to navigate through all these applications, ticketing systems, and journey planning steps with the increasing mobility options (Matyas, 2020). Also, as these different transportation modes are operated individually under the respective commercial applications, it is difficult to plan trips from the exact starting point to the end point. The aforementioned challenges and the growing shared mobility economy have enabled the concept of MaaS, which was discussed to change the paradigm of mobility by integrating different mobility services into a single, user-friendly platform.

MaaS is a recent concept that has been studied for nearly 10 years. The idea is first mentioned and promoted as *transport as a service* in a paper called "The Transport Revolution" published by the Finnish Ministry of Transportation and Communication in 2011 (Hietanen, 2020). Then, Sweden has developed the first pilot MaaS application UbiGo in 2013, and Finland has developed "Helsinki Model" in 2014 (Karlsson et al., 2016; Heikkilä, 2014). Later in 2014, the project Whim app is started in Finland based on the visions of Helsinki Model (Polydoropoulou, 2020). In 2016, MaaS International Alliance, an international public-private partnership that creates foundations for a common MaaS approach, has been founded to facilitate a single, open market and full deployment of MaaS services (MaaS Alliance, 2020).

After successful pilot projects and the establishment of MaaS Alliance, the concept was recognized worldwide and the number of pilot projects increased. Kamargianni et al. (2016) has classified these pilot projects according to their integration level: partial, advanced, and advance with mobility packages.

Existing MaaS pilots according to the above classification are given in Table 1 (Kamargianni et al. 2016; Kriukelyte, 2018; Aries-Molinares and García-Palomares, 2020)

Table 1. Existing MaaS pilots

Level of Integration	Explanation	MaaS Pilots
Basic	Partially possesses ticketing, payment, and ICT integration	Moovel, Switchh, Qixxit (Germany) and Cambio-STIB (Belgium)
Advanced	Fully possesses ticketing, payment, and ICT integration	Mobility Shop, Open Mobility (Germany), Smile (Austria), and Optymod (France)
Advanced with mobility packages	Offer monthly packages and pay-as-you-go options	UbiGo (Sweden), Whim app (Finland), Antwerp (Belgium), and West Midlands (UK)

Although there are successful implementations, the dissemination and future of MaaS still depend on technological, social, and regulatory developments (Sarasini et al., 2018). Advanced applications of MaaS offer an integrated mobility service that consists of public transportation (bus, tram, ferry, etc.), car-sharing services, bike-sharing, and cab services while providing different monthly subscription services according to the demand and need of users (Giesecke et al., 2016). To achieve such a system with different stakeholders and options available, components of MaaS should be identified and examined in detail on the local scale.

3. COMPONENTS OF MaaS ECOSYSTEM and THE FUTURE OF MaaS

MaaS applications are mostly implemented in urban areas where required transportation infrastructure and necessary organizations already exist (Jittrapirom et al., 2018). The main aim is integrating these organizations and maximizing the infrastructure's performance to achieve a sustainable transportation management system. Since features of cities such as sociological texture, existing infrastructure, available transportation modes, or topography are different and unique, MaaS approaches should be examined on a local scale. Its success depends on the management of user behaviors, governmental/local policies, private sector contribution, deep research and modeling of systems, ICT infrastructure developments, and strong collaborations between these components. The major components and their relations within the MaaS ecosystem are shown in Fig. 1.

From the user's point of view, a MaaS operator must offer tailored and customized mobility packages according to the needs. Optimizing the interaction between user and MaaS is a challenging factor as many different personal attitudes such as health conditions, age, social behaviors, attitudes, and financial income are taken into account in mobility. MaaS operator should provide a list of public and private travel options including traditional and new transport modes while considering the preferences and travel budgets of the user (Jittrapirom et al., 2017).

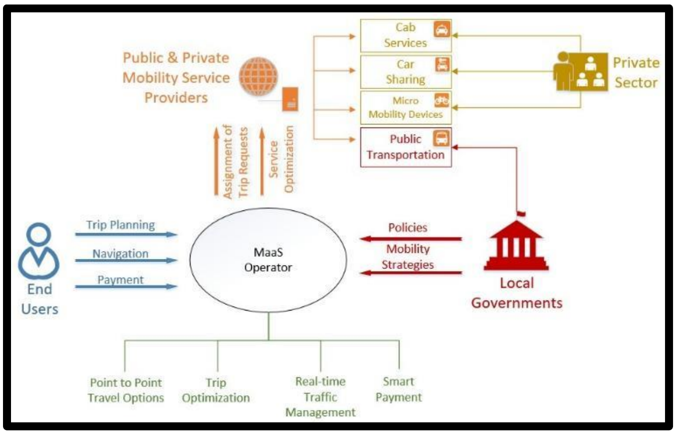

Figure 1. Components and their relations in the MaaS ecosystem

The strength and sustainability of the system depend on the provision of personalized real-time travel and activity planning alternatives within the MaaS operator. To optimize these needs, advanced technological techniques and methods should be used. For example, the Whim app of Helsinki, Finland has four different subscription methods consisting of different transportation modes and payment methods (monthly subscriptions & pay-as-you-go) according to the sociological pattern of citizens. Additionally, the sustainability of the system is supported by real-time user attitude data through these methods.

On the supply side, the MaaS operator must maintain the distribution and assignment of trip requests among mobility service providers. In that stage, strong collaboration between service providers (public or private) and the MaaS operator must be established through Application Programming Interfaces (APIs) to offer real-time mobility options to the users. In an advanced example of MaaS, even real-time traffic management could be performed with real-time data.

Transport authorities have vital importance to achieve a sustainable transportation system through MaaS. They play a key role by promoting collaboration between different stakeholders (Chang et al., 2019). They have a dominant impact on public transport operators that are the backbone of MaaS and the potential to enable MaaS through policies, regulations, and frameworks (Audouin, 2019). After enabling MaaS, a strong system fed with real-time data and user behaviors will help policymakers to get a clear vision about the current situation and to define mobility strategies to make future transport smarter, cleaner and equal (Pangbourne et al., 2018).

The effects and benefits of MaaS depend on the spatial scale of the city to be implemented. Therefore, before initiating the system at the conceptual level, existing examples, and unique spatial requirements & opportunities should be deeply researched. Integrated demand and supply mechanisms of MaaS should be investigated via advanced modeling, simulation, and optimization methods. Its ecosystem consists of many components in social, economic, spatial, and technological domains. Therefore, conventional modeling and simulation methods need to be enhanced to get clearer insights about the framework (Ho et al, 2018; Basu et al., 2018; Stiglic et al., 2018).

In the spatial domain, since there are many different types of user groups and available services in the ecosystem, the impacts of MaaS on transportation should be modeled and examined in detail in a Spatial Information environment. MaaS is an accessibility-based concept that includes multi-modal transportation, therefore these modes should be examined with different accessibility and network (transportation modes) parameters. Each mode of transport has different mobility characteristics such as being stop-based (bus, subway, etc.) or access-based (from A to B such as car-sharing or cab). Therefore, the integration of these unique features into a spatial application requires tailored network optimization techniques. Collecting valuable data as well as enhancing data through analysis and simulations is vital to ensure this integration. The ecosystem should be analyzed in detail through advanced network analysis to reveal impacts in terms of social, economic, and mobility convenience.

An advanced ecosystem should offer the integration of these services while helping to reduce carbon emissions. The term "sustainability" in the definition of MaaS also includes environmental sustainability. Therefore, besides the impacts on mobility, effects of MaaS on land use and environment should be modeled with advanced modeling techniques such as land-use interaction models or agent-based modeling to evaluate the different mobility scenarios. Additionally, the effects and contributions of the MaaS ecosystem to the sustainability and demography of the city should be evaluated with Artificial intelligence and machine learning techniques, as these tools can dynamically predict travel conditions and be used to automate processes.

4. CONCLUSION

MaaS is an emerging technology that is still being studied. It has several examples around the world, yet certain definitions, impacts, and benefits are uncertain. In this paper, existing implementations and the core elements of the architecture are examined and the future of MaaS is discussed. Although defining a precise roadmap is difficult, this paper is intended to be a basic reference and literature review for future studies.

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