Review on Mobility as a Service in Scientific Publications

Abstract

Our current private car based transport system is inefficient and unsustainable. The Mobility as a Service (MaaS) model aims to provide seamless trips over one interface by combining different transport modes and services. This study analyses MaaS-focused journal articles and conference papers found in Scopus and ScienceDirect databases in June 2018, and aims to help the scientific community and MaaS stakeholders to recognize the current state of the art of MaaS research findings, and where to focus in future. The recognised 31 MaaS-focused publications were categorised in three groups according to their main issues discussed; the roles of different transport modes and services in MaaS, the findings of MaaS pilots and trials, and the expected effects of MaaS. In these three categories, we present the key findings and discuss the future research avenues. The MaaS research has had a strong focus on private car users and how to change travel patterns of this user group. In order to attract new users, mobility services and sustainable transport modes should be able to provide a higher service level. A successful MaaS implementation is expected to be able to decrease the use of private cars and increase the use of sustainable transport modes.

Keywords

Mobility as a Service; Integrated mobility; Literature survey

1. Introduction

Increasing traffic volumes in cities because of urbanization, the need to decrease the greenhouse gas emissions, and the constantly varying mobility needs call for new solutions for daily transport (El Zarwi*[1] et al., 2017). Sustainable transport should be in the centre of the solutions, which challenges the current transport system, which is mainly based on private cars with underutilized capacity (Strömberg et al., 2016). Everyday travelling from place to another should be possible by integrating flexible mobility options serving users' needs. Competitive choices for private cars are called for, and Mobility as a Service (MaaS) is considered as one option as it offers a new paradigm by placing user's needs in the centre of the transport system.

The scientific community and MaaS stakeholders need up-to-date information on state of the art research on Mobility as a Service. However, a comprehensive literature review of journal articles and conference papers on MaaS has not been conducted. Previous reviews on MaaS have mainly focused on MaaS trials and implementations. Kamargianni et al. (2016) listed existing MaaS schemes and evaluated mobility integration level of the schemes. Jittrapirom et al. (2017) collected different MaaS definitions and formed an overview on MaaS schemes. Smith et al. (2018a) classified some articles and conference papers related to MaaS, but the contents of the studies were not reviewed.

As MaaS is a new paradigm in the transport system, the research in around MaaS has only began a few years back. Based on scientifically published journal articles and conference papers, this paper aims to summarise, what are the key issues addressed and the key findings presented in the scientific publications on MaaS. Firstly, the paper aims to answer:

[1] The asterisk symbol (*) relates to the method and materials used in this study. See section 3 for more details.

- What are the main topics and issues, which MaaS research has discussed and what has been the main findings in the studies?

After analysing the scientific publications, we categorise these in three identified groups. These categories, presented in section 3, relate to the following questions, which this study aims to answer based on existing literature:

- What is the role of different transport modes and services in MaaS?
- What are the key findings from MaaS pilots and trials?
- What are the expected effects of MaaS?

The study is conducted by analysing the scientifically published articles and conference papers from two databases focusing on Mobility as a Service. The study aims to assist the scientific community and the various MaaS stakeholders to recognise the current state of the art in MaaS research.

The paper is structured as follows: section 2 describes the MaaS concept. In section 3, the research framework and the literature review are depicted. Thereafter the three different research issues are discussed and presented in sections 4, 5, and 6. Finally, section 7 discusses the main findings, and presents the conclusions.

2. Mobility as a Service

Hietanen* (2014) and MaaS Global* (2018) state that Mobility as a Service concept aims to combine different transport modes (e.g. public transport, car-sharing, ride-sharing, taxis and bicycles) to seamless trips over one user interface. Combining the use of public and private transport enables smooth mobility options and provides alternatives for travelling (Melis et al., 2016; Melis et al., 2017). The main idea in MaaS is to fulfil mobility needs without the need to own a private car or various travel cards from different public transport companies or mobility service providers (Ambrosino et al., 2016; Giesecke et al., 2016). It is not novel that a journey to the destination can be made by combining different transport modes and services, but according to the new paradigm the whole package can be booked and paid with a mobile application (Hensher, 2017). The new concept should not only include the existing transport modes but also offer better circumstances, e.g. higher service level or lower costs, simultaneously (Giesecke et al., 2016).

Disabled passengers' difficulties to use a private car or public transport can be defeated in this new service concept (Atasoy* et al., 2015). Particularly ride-sharing and taxi services can be more affordable as a part of the system, which provides better opportunities for disabled people. Generally speaking, conventional public transport cannot provide as good service level as a combination of other transport modes because public transport has fixed schedules and routes (Atasoy* et al., 2015). MaaS can make it possible to reach the destination at a higher service level (e.g. more comfort and less travel time), with a more expensive price or at the best possible price, if the service level is not the priority (Melis et al., 2016).

A MaaS platform covers all necessary mobility operators that are needed to provide flexible and customized transport to different kinds of users (Kamargianni et al., 2016). As the mobility operator knows the real-time conditions of network (e.g. supply and demand), the operator is able to propose an ideal trip chain including route planning to a destination (Kamargianni & Matyas* 2017). The service portal forms the wanted trip chain on behalf of the customer and enables travelling the whole trip via a single payment or a mobility package (Hietanen*, 2014; Kamargianni et al., 2016). Thanks to integrated mobility services, the customer does not need to buy separate tickets for different services and the trip chain can be made by a single payment.

In order to provide integrated services, which enhance daily mobility options, real-time data of supply and demand is needed (Melis et al., 2017). Integrated mobility services are complex systems as they gather information (e.g. timetables, real-time traffic data, car-sharing availabilities etc.) from various sources (Hilgert* et al., 2016) and from various organisations. Furthermore, customer's need to carry any kind of goods is also considered, and additionally, applicable use of data enables MaaS to combine transport of passengers and goods to the same vehicle (Giesecke et al., 2016).

Flexible and customer specified trip chains require a wide MaaS ecosystem. According to Kamargianni & Matyas* (2017), the MaaS ecosystem consists of the MaaS provider, data providers, transport operators, customers and technical solutions and infrastructure (e.g. ticketing and payment solutions, journey planners and ICT infrastructure). The role of the MaaS provider or organizer is crucial as the provider cooperates between the actors, uses the mobility data and manages the ecosystem. The digital platform is the basis for all the interactions within the ecosystem' actors and thus highlight the role of technical solutions in successful MaaS implementations (Jittrapirom et al., 2017).

In order to work properly, the service-oriented transport system demands actions from the public administration, which is why the role of public administration is significant (Ozaki, 2018). It should be ensured that the roles, responsibilities and collaboration regarding mobility operators and institutes that are in charge of the whole system are appropriate from mobility services' point of view. If regulation of transport will be updated to meet the operating conditions of MaaS, service supply is expected to expand considerably (Hensher, 2017). The public administration itself could act as an upper level organizer and thus would be responsible for the collaboration of operators or a private company could have the role of the central MaaS operator (Melis et al., 2016). Anyway, as public transport is expected to play a key role in the new paradigm, the public transport authorities are key stakeholders as one of the upper level MaaS organizers (Ambrosino et al., 2016). As MaaS is in an innovation and development phase, stakeholders and authorities should plan the wanted long-term position instead of the current position to better understand where to focus in the development process (Docherty et al., 2017).

3. Materials and methods

Analysis in this paper is based on a literature study of peer reviewed journal articles and conference papers. The search for relevant publications was made in Scopus[2] and ScienceDirect[3] databases in June 2018. These databases were used as they include a large amount of scientific publications. Scopus (2018) claims to be 'largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings', whereas ScienceDirect (2018) is Elsevier's platform of peer-reviewed scholarly literature and allows searches in over 3,800 journals. We found 66 and 69 publications including the expression 'Mobility as a Service' in Scopus and ScienceDirect, respectively. 13 same publications were found in both databases. 31 of the 122 (66 + 69 - 13) publications were actually fully MaaS-focused, and thus relevant for our study. Of the relevant literature, 20 are journal articles (seven of them articles in press) and 11 conference papers. These are presented in Table 1. The non-related publications (91 of 122), which included the statement 'Mobility as a Service' but were not MaaS-focused, discussed e.g. mobile networks or MaaS was only a minor part in the study, e.g. MaaS was discussed only in one paragraph.

Based on their topics and issues, the 31 scientific articles and conference papers were categorised into three groups, which are partly overlapping each other. We identified three main issues, which were discussed in the publications; 1) the roles of different transport modes and services in MaaS, 2) the findings of MaaS pilots and trials, and 3) the expected effects of MaaS. Besides these topics, some publications discuss the architecture and mathematics behind a mobility application or a scheme, but as this study focuses especially on mobility and transport system issues, these are not analysed in this paper as an own category. Many studies discuss a specific transport mode or some modes as a part of the MaaS scheme and thus the first group is justified and needed. The two other groups are somewhat similar. The second group describes results of MaaS trials whereas the third group discusses the larger impacts MaaS has to the transport system based on experts' assessments and common observations from trials. It is important to recognise that currently there are no scientifically published research results regarding wide and comprehensive MaaS schemes, and thus the findings are commonly based on expert opinions and the results from MaaS pilots.

In MaaS-focused publications, the expected effects of MaaS (group 3 in Table 1) has been the most popular topic as 15 of the 31 publications discuss this topic. 10 publications were categorised to group 2 and the rest six studies to group 1. Division to the specific groups was made based on the main topics of the publications. However, some publications discussed several topics and thus they could be placed to another group beside of the main group.

[2] www.scopus.com (accessed: 4.6.2018)
[3] www.sciencedirect.com (accessed: 4.6.2018)

Table 1. The scientific articles and conferences papers found in Scopus and ScienceDirect in June 2018 with the expression 'mobility as a service' and a MaaS-focus. Article group refers to the analysis of the main issue of the article, where 1 = the roles of different transport modes and services in MaaS, 2 = the findings of MaaS pilots and trials, and 3 = the expected effects of MaaS.

Author(s)	Name of publication	County of main author's institute	Publication type	Year of publication	Article group
Ambrosino et al.	Enabling intermodal urban transport through complementary services: From flexible mobility services to the shared use mobility agency: Workshop 4. Developing inter-modal transport systems	Italy	Article	2016	3
Brendel & Mandrella	Information systems in the context of sustainable mobility services: A literature review and directions for future research	Germany	Conference paper	2016	3
Callegati et al.	Cloud-of-Things meets Mobility-as-a-Service: An insider threat perspective.	Italy	Article	2018	3
Docherty et al.	The governance of smart mobility	United Kingdom	Article in press	2017	3
Frei et al.	Flexing service schedules: Assessing the potential for demand-adaptive hybrid transit via a stated preference approach	United States	Article	2017	1
Giesecke et al.	Conceptualising mobility as a service	Finland	Conference paper	2016	3
Heikkilä	Reorganization of the mobility service provision - Public governance as a contributor	Finland	Conference paper	2014	3
Hensher	Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change?	Australia	Article	2017	1
Jittrapirom et al.	Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges	The Netherlands	Article	2017	3
Jokinen et al.	Policy lessons from the flexible transport service pilot Kutsuplus in the Helsinki capital region	Finland	Article in press	2017	2
Kamargianni et al.	A critical review of new mobility services for urban transport	United Kingdom	Conference paper	2016	2
Kamau et al.	Demand responsive mobility as a service	Japan	Conference paper	2017	2
Karlsson et al.	Developing the 'service' in mobility as a service: Experiences from a field trial of an innovative travel brokerage.	Sweden	Conference paper	2016	2
Katsuki & Taniguchi	Introducing mobility sharing with automated driving: Reducing time and space for parking	Japan	Conference paper	2018	3
Lamotte et al.	On the use of reservation-based autonomous vehicles for demand management	Switzerland	Article	2017	2
Matyas & Kamargianni	A stated preference experiments for mobility-as-a-service plans	United Kingdom	Conference paper	2017	3
Melis et al.	Public transportation, IoT, trust and urban habits	Italy	Conference paper	2016	3
Melis et al.	Integrating personalized and accessible itineraries in MaaS ecosystems through microservices	Italy	Article in press	2017	2
Mulley et al.	Community transport meets mobility as a service: On the road to a new a flexible future.	Australia	Article in press	2018	1
Nikitas	Understanding bike-sharing acceptability and expected usage patterns in the context of a small city novel to the concept: A story of 'Greek Drama'	United Kingdom	Article	2018	2
Ozaki	Technical standardization of ITS and Asian initiatives for intelligent mobility	Japan	Article in press	2018	3
Pakush et al.	Using, sharing, and owning smart cars: A future scenario analysis taking general socio-technical trends into account	Germany	Conference paper	2016	1
Rantasila	The impact of mobility as a service concept to land use in Finnish context	Finland	Conference paper	2016	3
Sarasini & Linder	Integrating a business model perspective into transition theory: The example of new mobility services	Sweden	Article	2017	3
Signorile et al.	Mobility as a service: a new model for sustainable mobility in tourism	Italy	Article	2018	3
Smith et al.	Mobility as a service: Development scenarios and implications for public transport.	Sweden	Article in press	2018	1
Smith et al.	Public–private innovation: barriers in the case of mobility as a service in West Sweden	Sweden	Article	2018	2
Strömberg et al.	Trying on change - Trialability as a change moderator for sustainable travel behaviour	Sweden	Article	2016	2
Thai et al.	Resiliency of mobility-as-a-service systems to denial-of-service attacks	United States	Article	2016	3
Vanderschuren & Baufeldt	Ride-sharing: A potential means to increase the quality and availability of motorised trips while discouraging private motor ownership in developing cities?	South Africa	Article in press	2018	1
Walker & Marchau	Dynamic adaptive policymaking for the sustainable city: The case of automated taxis.	The Netherlands	Article	2017	2

The scientific articles with a MaaS-focus have been published in various journals, and the topics of MaaS-articles vary in the different journals. The most popular journal has been the Journal of Research in Transportation Economics with four articles with MaaS-focus published.

Most of the scientific article and conference paper writers have been first author only in one of the publications listed in Table 1, which make the author base of MaaS publications broad when considering the number of publications. Analysis on the first writer's institution reveal that writers of the publications are mainly from universities. Additionally, the main writer's institution has been a consultant firm, a research centre or a municipality. Based on the nationality of first writer's institution, MaaS-focused research seems to have a strong basis in Europe (23 publications) and particularly in Italy and Sweden, both with five publications. The main author's institution is from Finland and the United Kingdom in four publications. Overall, the first writers' institutions represent organisations from the developed countries.

It can be clearly observed that research on MaaS is topical in scientific publications as the amount of studies in Scopus and ScienceDirect databases including the term 'mobility as a service' was 64 in June 2017, but in June 2018 already 122, indicating almost a doubled amount of studies. The amount of MaaS-focused publications also almost doubled in a year from 16 to 31. The earliest publication in Table 1 is a conference paper from Heikkilä (2014) in which Heikkilä introduced a MaaS concept for the City of Helsinki based on her master's thesis. The amount of scientific publications with a MaaS-focus began to increase in 2016.

To answer our research questions, we focus on the publications in Table 1, but as there is also other relevant literature related to different topics discussed in this article, we refer to these, e.g. news from companies' web pages, other scientific publications and different research reports, when needed. These publications are marked by an asterisk after the author's name (e.g. Mattioli* et al., 2016) to discern these from the 31 MaaS-focused publications listed in Table 1. Additional literature was identified by looking into the references used in the 31 publications and with relevant search terms e.g. mobility services or car-sharing etc. in internet databases. The role of the other literature is to complement the specific issue (e.g. role of cycling in MaaS) when MaaS-focused publications are not discussing all the relevant aspects.

It's worth to note that our main focus is in the recognised MaaS-focused publications, and other MaaS literature was not systematically analysed. The publications in Table 1 are such which explicitly include the term 'mobility as a service'. Besides these, there are many publications which relate to MaaS, but are not included in our 31 MaaS-focused publications. E.g. Atasoy* et al. (2015) does not use the term 'mobility as a service', but discussed a MaaS-trial at a conceptual level, and Huwer* (2004) discussed the role of car-sharing and public transport and effects of their combination, which are highly relevant for section 4.

4. The roles of different transport modes and services in MaaS

The current roles of different transport modes and services are expected to change to fit to service-oriented transport system of the future. This section describes the relationship

between MaaS and the changes in different transport modes and services. The section is divided three parts: cars, public transport and cycling. The section on cars discusses motor vehicles such privately owned cars, car-sharing, car rental, and taxis.

4.1 The role of cars in MaaS

One of the key issues in MaaS is the role of the car. The fundament of new mobility services is the possibility to seamless and reliable mobility without owning a car (Ambrosino et al., 2016). Changes in car ownership would probably mean more popular times for car-sharing. Car-sharing offers similar options as private cars but without ownership and encourages to try alternative modes. When car-sharing is one of the alternatives instead of a private car, the actual cost of the trip is easy to compare to other modes (Huwer*, 2004). Consequently, the different transport modes are at the same starting point when owning a car is not distorting the choice of transport mode. A successful car-sharing service requires a crowd and is thus most suitable in a high-density urban structure (Giesecke et al., 2016). An own car is a good option especially if there is often heavy goods or many children to carry, which needs to be considered when service providers and authorities develop new services (Mattioli* et al., 2016), and MaaS schemes are designed and implemented. Acceptability of advanced mobility solutions such as ride-sharing services should be examined carefully before implementations since the acceptability may vary between different countries (Vanderschuren & Baufeldt, 2018).

Free-floating car-sharing is a modern model compared to station based car-sharing as the free-floating service enables to pick up a car anywhere within the operation area as long as the car is free, and to drop off the car within the same area (Becker et al.,* 2017a). The traditional station based service, in which the beforehand determined starting point and end point for a trip restrict the service, is assessed to affect more towards using sustainable transport modes than free-floating car-sharing (Becker et al.,* 2017a). Overall, car-sharing in its alternative ways is an important factor in the MaaS concept, but as a separate service it does not provide revolutionary changes (Giesecke et al., 2016). MaaS has therefore an important role in making car-sharing a part of the users' mobility options.

It is still unclear, who is going to own the cars in the future but someone has to be the owner (Hensher, 2017). Nowadays the majority of the cars are owned by households. Consequently, it seems unlikely or at least it takes several years before other actors, e.g. car-sharing companies, become the dominant owners. Car-sharing companies of today may not be capable of owning a very large number of vehicles, which could be the reason why private persons release their cars to joint use but still own the cars (Hensher, 2017). The rapidly developing self-driving cars could change mobility considerably if they are utilized as a service. Pakush et al. (2016) estimated that some of the self-driving cars will be privately owned and rest of them used as a service, and this combination would reduce the amount of cars on roads. Present-day services such as Uber and Lyft are already part of the transport system's services but their business model may have too little upgrades compared to regular taxis for being a successful member of MaaS (Giesecke et al., 2016). MaaS is likely to affect the taxi services, but it is not clear, what is the magnitude of the effects (Walker & Marchau, 2017).

Decreasing car traffic has positive impacts to climate and urban space and hence the car ownership is an important question (Huwer*, 2004). In itself, car-sharing is not more environmentally friendly than any other way of car usage as it also causes congestion but car-sharing companies typically offer newer and smaller cars than e.g. Uber (Giesecke et al., 2016). However, when the cars are not privately owned, there is, supposedly, a bit higher threshold to travel by the car. In a service-oriented transport system, driving a car, which can be in the form of car-sharing, can be managed better at the strategic level, which may reduce car traffic (Huwer*, 2004).

The role of cars could change significantly if the new paradigm was adopted (Hensher, 2017). If the whole spectrum of mobility options would be available through an integrated service, there would be a great potential to mobility without owning a car. Decreased level of car ownership is seen to lead to increased use of alternative transport modes, hence raising the popularity of shared mobility services and directing mobility to a more sustainable direction (Giesecke et al, 2016; Karlsson et al., 2016). Bookable on-demand services (e.g. a shared taxi service) as a part of a comprehensive MaaS concept include inconveniences compared to private cars, which is a reason why MaaS needs to offer other benefits like avoiding congestion because of appropriate start time proposed by the service portal (Lamotte et al., 2017).

4.2 The role of public transport in MaaS

The increasing use of private cars has created difficulties to conventional public transport during the recent decades (Ambrosino et al., 2016). At the same time, digitalization has made the use of buses and trains easier as electronic payment, web based route planning and real-time information has been introduced (Melis et al., 2016). However, conventional public transport needs to adapt to MaaS as the current model is not that flexible to offer customer-focused mobility, which is the basis of the MaaS model (Hensher, 2017). Reliable car-sharing and on-demand services may decrease the number of passengers in public transport but MaaS can also provide new ways to develop public transport. MaaS enables public transport to be an integral part of the modern society promoting mobility options for everyone including e.g. aged people (Mulley et al., 2018).

According to Smith et al. (2018a), public transport within MaaS can be developed in different ways e.g. by market-driven, publicly controlled or co-operated between public and private actors. The amount of regulation is important: intense regulation decreases private sector's willingness to innovate, but too negligible regulation does not benefit users and authorities. Typical model with geographic boundaries in supplying public transport restricts the flexibility of public transport to operate as a point-to-point service (Hensher, 2017). By using smart technologies, flexible point-to-point services can be offered by demand-based systems together with conventional services with timetabled routes (Hensher, 2017). As an advantage in flexible public transport, trip's point of origin can be the waiting place and hence there is no need to wait on a bus stop. From the car driver's point of view this may lead to perceive flexible public transport more attractive than conventional public transport. (Frei et al., 2017) Adaptation of public transport to the model that fits in MaaS requires more experiences e.g. on how a service-oriented transport system affects people's mobility.

Travelling by a privately owned car could be reduced as new services can exploit real-time data on demand, thus produce enhanced service level of public transport and promote connectivity with other modes (Hensher, 2017).

How efficiently public transport can be integrated to other modes is a crucial question for the future role of public transport. Hensher (2017) presented two scenarios including a combination of bus services and Uber-type point-to-point services, which is a possible scenario for the future as well as the combination of bus services and ride-sharing. Point-to-point services would consist of integration of conventional taxis and public transport. Ride-sharing would instead mean point-via-point-to-point services, which is more like conventional public transport than car traffic but the cost is lower. In ride-sharing, a small bus could replace a car if the amount of passengers is appropriate, but at the same time a fleet of small and large buses would add maintenance costs. It is however unclear how these kind of solutions would affect the system and how bus contracts (e.g. sharing profits) would be organized in a MaaS model. (Hensher, 2017)

According to the experiences from Germany and Switzerland, car-sharing acts as a strong supplement for public transport and it also enables giving up car ownership, which further increases the use of public transport (Becker* et al., 2017b; Huwer*, 2004). Without car-sharing option, public transport oriented lifestyle could be difficult to maintain (Huwer*, 2004). Furthermore, residential area's enhanced accessibility has a connection to a decreasing number of privately owned cars and an increasing number of season tickets for public transport (Becker* et al., 2017b). Purchasing a car or giving it up reflects a lifestyle change resulting in changes in mobility behaviour (Huwer*, 2004).

4.3 The role of cycling in MaaS

The discussion considering the role of cycling under the MaaS model is missing in almost all MaaS-focused publications listed in Table 1. It has been mentioned that bike-sharing is an important part of a comprehensive service system (e.g. Ambrosino et al., 2016; Kamargianni et al., 2016), but discussion has mainly focused on other transport modes, especially on private cars, car-sharing, taxis and public transport. Yet, free-floating bike-sharing services offer an easy way to use bikes as the system includes several pick up and drop off points, and because of environmental aspects promoting bike-sharing is worthwhile (Tomaras* et al., 2017). As bike-sharing could be seen e.g. as a first or last-mile solution in bigger cities (Nikitas, 2018), MaaS could enhance use of bike-sharing by integrating mobility services and making the payment and routing easier.

Observations related to bike-sharing systems reveal that bike trips are typically short (usually less than 10 minutes) and this relates especially to most active users (Caulfield* et al., 2017; Tomaras* et al., 2017). Furthermore, active bike-sharing system next to a fixed bus route has been assessed to decrease bus ridership in New York City (Campbell & Brakewood*, 2017). However, in these studies bike-sharing has been studied as separate system from MaaS. It would be worthwhile to understand the role of bike-sharing compared to car-sharing and ride-sharing services as a part of a MaaS scheme. Current bike-sharing users would be likely users of MaaS as bike-sharing members have been assessed to be

more willing to try new services (e.g. flexible public transport) compared to others (Frei et al., 2017).

It is still unclear what the role of cycling will be in MaaS as we are lacking proper knowhow of larger scale MaaS schemes. On one hand, bike-sharing services could increase the amount of cycling trips as bike can be chosen for only one part of the trip chain and the bike is easy to access from multiple stations by e.g. using a smart phone. On the other hand, car-sharing services offer easy access to automobiles, and ride-sharing services provide lower cost mobility. These are comparable choices for bike-sharing to some extent. Ride-sharing and demand responsive transport also offer more applicable pick up points for passengers compared to current public transport. This would decrease the walking distances to access these modes. In conclusion, MaaS promotes several mobility options, which make it hard to assess the future role of cycling in MaaS.

5. Findings from MaaS pilots and trials

This section introduces MaaS pilots and schemes or visions of them. The focus is on describing the experiences and effects of the trials discussed in the analysed 31 scientific publications. As a notable issue, the most advanced MaaS systems are still at a conceptual level or are just introduced to the markets, resulting in low amount of results from studies. Thus, there are not many scientific publications available related to the MaaS implementations. To support the analysis presented in this section, different MaaS offerings are used as examples of the current state of the practice.

5.1. MaaS schemes

Kamargianni et al. (2016) stated that the highest level of MaaS schemes consists of ticket, payment and ICT integration and provides also mobility packages for the customers. Advanced level MaaS systems like Whim, UbiGo, Tuup and SHIFT enable connecting various transport modes and services to an easy trip chain under a single platform, e.g. in a mobile app. The systems also allow the customer to plan the trip from point-to-point and to pay the whole trip at once or via package. These schemes integrate bike-sharing, car-sharing, car rental, public transport and taxis together. As an example of an advanced system, Tuup's taxi service, Kyyti, consists of on-demand taxis. Kyyti provides regular taxi with normal price but also cheaper shared taxi services with longer waiting and travel time (Tuup*, 2018). SHIFT also offered one form of on-demand taxis as it offered cars owned by the company with drivers (Project100*, 2017).

Tuup and Whim offer their MaaS schemes currently (in June 2018) in Finland. Whim has also expanded its services to West Midlands in the UK, Amsterdam in the Netherlands, and Antwerp in Belgium (Whim*, 2018). UbiGo had a six months trial in Gothenburg, Sweden, already in 2013 and second version is planned to run Stockholm, Sweden (UbiGo*, 2018). SHIFT was introduced in Las Vegas in the USA in 2013 but the service has been discontinued (Project100*, 2017).

Kamargianni et al. (2016) assembled different MaaS schemes worldwide and created an index, and assessed the schemes based on the integration level (ticket, payment, ICT and

mobility package integration). According to the index, the higher the integration level and the higher number of transport modes and services included in the scheme, the higher is the level of the MaaS scheme. The study assessed 15 MaaS schemes and most of them got a comparably high score. In this index the so called Helsinki Model, a vision for the future that Heikkilä (2014) presented got the highest score. UbiGo and SHIFT were among the best in this comparison. Whim and Tuup were not included in the study as they were not established at the time of the comparison.

Several other MaaS-related systems or applications have been created but they do not integrate the main transport modes to one system or integration (e.g. ticket and payment) is lacking and thus the system is incomplete. A crucial part of customized mobility options in future is demand responsive transport (DRT). Kamau et al. (2017) created Demand Responsive Mobility as a Service (DRMaaS), which is a transport service in the middle ground between taxi and bus services. Testing DRMaaS in Dhaka, Bangladesh, indicated a reduction in waiting time and the travel time was on average almost the same as by bus. The cost was more expensive than travelling by a bus but clearly more inexpensive than by other modes. Atasoy* et al. (2015) developed a simulation trial called Flexible Mobility on Demand (FMOD) service, which provided customized service to end-users, but the service system is not comprehensive as it solely consist of taxi, shared-taxi and minibus services. In Helsinki, Finland, a flexible on demand transport called Kutsuplus ran from 2012 until the end of 2015, but despite presenting great potential, the ride-sharing minibus service ended because of financial issues and scalability problems (HSL*, 2017).

One of the purposes of MaaS platforms is to make it easier to manage everyday travelling as our transport system with multiple mobility options is somewhat complicated (Hilgert* et al., 2016). The personal mobility assistance described by Hilgert* et al. (2016) is an example of a MaaS platform filling especially this purpose. Furthermore, the platforms benefit the service providers by enabling them to integrate the needed external components (such as a bus tracking service including e.g. timetable services) to the existing system (Melis et al., 2017). A marketplace for mobility services called Smart Mobility for All (SMAll) introduced by Melis et al. (2017) is capable of integrating different data sources e.g. real-time transport data and pricing to enable trip planning for end-users and monitoring tool for authorities. The formation of a comprehensive service concept supports traveller's daily mobility. This type of comprehensive service includes e.g. trip's starting and ending time information, appropriate cost and travel time combined with intelligent ways to share information between transport operators.

5.2. Findings from MaaS trials

As the current amount of comprehensive MaaS schemes is low and they are newly established, there is not much research published on the findings. UbiGo's trial is one of the few high-level schemes on which there is published questionnaire data on participants' experiences. Survey data of 151 users of the UbiGo pilot revealed that the participants increased their use of car-sharing and public transport while decreased their use of private cars during the trial. The trial integrated several transport modes under one payment package. An interesting detail is that customers overestimated their need to use car-sharing

service as they purchased more car hours than they used during the trial. This could be a result of changing car trips to other transport modes. (Karlsson et al., 2016; Sochor* et al., 2015b)

Almost all pilot users would have been interested in using UbiGo after the end of the pilot. It was mentioned that the service, which was used through a mobile app, caused problems to some customers and thus help desk via telephone and even special guidance meetings were worth to be arranged. To sum up, users became more negative towards private cars and more positive towards alternative modes due to UbiGo trial. (Karlsson et al., 2016)

A MaaS application may increase the use of sustainable transport modes as well as enhance user acceptance concerning mobility services. Without a MaaS bundle, the availability of various mobility options and flexible working conditions cause difficulties to choose a trip chain (Hilgert* et al., 2016). Particularly high-level MaaS schemes with multiple modes and integration of necessarily attributes are expected to increase the demand for the new service concepts (Kamargianni et al., 2016). A key issue is to manage user's travel behaviour in a better way with these new tools (Hilgert* et al., 2016).

MaaS trials can have an enormous role in changing people's mobility patterns. Even though a person may have an intention to change one's mobility behaviour to a more sustainable direction, it is, however, difficult to evaluate the actual results of the change in personal life and this is why trials enable a safe way to try new modes (Strömberg et al., 2016). Especially, to give up owning a car and to adopt new mobility services causes hesitation and consequently mobility habits could remain as before. The MaaS trials have indicated that people's preconceptions have altered after the trial but it is important that duration of the trial is long enough (e.g. six months) in order to change one's mobility behaviour (Strömberg et al., 2016). Mobility service apps can also suggest to increase sustainable mobility (e.g. walking and cycling) to trip chains and thus encourage people to a healthier lifestyle (Melis et al., 2016). Apps and trials could have even a larger impact if they are considered as strategic tools to modify everyday mobility (Strömberg et al., 2016).

The trials are an important step to change the paradigm but they also reveal challenges related to MaaS. When starting the first MaaS implementation, the lack of MaaS experiences may cause hesitation and it can be challenging to trust other organisations within the new ecosystem (Smith et al. 2018b). Careful planning is essential when combining different services and transport modes offered by different operators into one MaaS scheme (Kamargianni et al., 2016). Furthermore, the end of the trial should not be the end of the MaaS scheme as long as user experiences have been positive (Karlsson et al., 2016). As public transport, which could be subsidised by taxes such in case of UbiGo in Gothenburg, plays a crucial role in MaaS, support from policymakers is needed to ensure enough funding and necessary regulations for a permanent system (Karlsson et al., 2016). Subsidised public transport challenges the MaaS provider's profit making strategy as customers can travel with e.g. a monthly paid ticket, which can be lower priced than what the MaaS provider is able to sell (Sochor* et al., 2015a). Finally, multidimensionality of the factors relating to the service should be considered in order to implement a sustainable system (Jokinen et al., 2017).

As MaaS should be able to compete with the current car-based system, it is important to develop the quality of the MaaS scheme enough before beginning to operate. International standardization of data-formats and APIs (application programming interfaces) is also required in order to provide technical possibilities for the background system of MaaS (Melis et al., 2017).

6. Expected effects of MaaS

Changes towards a service-oriented system have an impact to the whole transport system and its users. As MaaS is not yet widely and consistently adopted anywhere, the impacts described in this section are based on literature depicting observations of smaller projects and expert assessments. In MaaS, the transport system is created in a smarter way than by building new capacity and the convenience of a private car can be maintained without the burden of ownership (Hietanen*, 2014). MaaS seems to be a desired model from society's point of view as it offers more efficient use of transport modes and their combinations, and more efficient use of the infrastructure, which further promotes cost-efficiency of the investments already done (Rantasila, 2016). Furthermore, the possibility to combine travellers' needs and to supply public transport services more cost-effectively may reduce the demand for public subsidy to public transport (Hensher, 2017). The business models of MaaS providers and operators should be developed in a way that profitable business and sustainable transport services can be integrated (Sarasini & Linder, 2017).

In order to get people to change their current role from transport providers (driving a car from point-to-point) to customers (using mobility services), MaaS is required to be capable to fulfil the daily mobility needs. Actually, the current transport system is already providing several options to fulfil different needs since public transport is appropriate for many daily trips, taxis and bicycles provide flexibility to more specific individual needs, and car rental and sharing services can cover the rest of the mobility needs (Huwer*, 2004). The service-oriented system combines these different modes and services on behalf of the customer e.g. by creating instructions on how to reach the desired destination and making different mobility options easier to use. As added value of MaaS, trips are planned by a digital app (Hensher, 2017).

Foresight regarding the development of the transport system is challenging as we can solely assess how the novel technologies and social behaviour e.g. autonomous vehicles, car-sharing, ride-sharing etc. will affect mobility (El Zarwi* et al., 2017). Despite the recent hype related to e.g. autonomous vehicles, we have not that much understanding, whether people are going to adopt and utilize these vehicles in larger scale. El Zarwi* et al. (2017) presented a prediction model for new technology adoption. According to the model, one example of a successful way to find customers for car-sharing, which is expected to have an important role in MaaS, is to set a car-sharing station next to a larger technology company. Furthermore, men and high-income groups were estimated to have a more positive attitude towards new technology. These findings provide valuable knowledge on the issues that are useful to consider when planning a MaaS implementation. MaaS could also enhance tourists' mobility options by recognising their needs and direct their mobility towards sustainable options (Signorile et al., 2018). More flexible mobility for tourists could also promote the brand of a city.

The most evident change because of MaaS seems to be in the role of car as Hensher (2017) stated based on previous studies. Changes in car ownership could, for example, mean a reduced demand of parking space, which enables new possibilities for land use, and particularly creates space for something else (Rantasila, 2016). Katsuki & Taniguchi (2018) estimated that autonomous vehicles as a ride-sharing service could reduce the amount of private cars by 60% if current car users would use the service. Reduction in the required time and space for parking would also be enormous. However, it is not fully clear that change in car ownership would mean less demand for car parks and decreased level of congestion. As a consequence of MaaS, more efficient use of existing vehicles would decrease the traffic volume, but better services for personalised mobility (e.g. for disabled people) could mean increased traffic and eventually more congestion than in the current system (Rantasila, 2016). Since only a few studies have focused on the environmental impacts, the sustainability of MaaS requires more research (Brendel & Mandrella, 2016).

Ownership itself is not the difference maker in the terms of popularity of car travelling if the car-sharing and taxis are easy and affordable choices compared to others. However, the use of sustainable modes could increase in principle, when a private car is not all the time ready to depart right at the forecourt. When people are not 'forced' to use car, they can better choose the transport mode that fits their individual requirements (Karlsson et al., 2016). If people choose to replace conventional timetabled public transport services during peak hours with a flexible car-sharing services, congestion is still likely to remain (Hensher, 2017).

As individual mobility data becomes an integral part of service development and daily transport, information security and privacy are increasingly important factors to recognise. Melis et al. (2016) state that the privacy of customers should be secured more reliably when the service system is led by public administration, while private companies in charge could lead to uncertainty in data collection and usage, even though market-based mobility services also offer benefits. Another information security aspect is Denial-of-Service attacks, which could affect the society widely as mobility is increasingly dependent on data and information systems (Thai et al., 2016). Moving towards self-driving cars would even emphasize this aspect, when abusers could affect the safety and road traffic.

7. Discussion and conclusions

Based on the reviewed scientifical publications, Mobility as a Service could be defined as a concept in which individual's mobility needs can be fulfilled effectively and more sustainably than currently by integrating different transport modes and services to seamless journeys. This requires an open platform for the cooperation of various mobility operators. As a new approach to mobility, service-oriented transport system demands adjustment from users, operators and public administration.

MaaS is a still a very young concept, and the amount of MaaS-focused research is rapidly increasing. The actuality of MaaS as a topic is also visible in scientific publications, the amount of which has increased strongly in 2017 and 2018. With the principal limitation to scientific literature with explicitly Mobility as a Service as a term in Scopus and ScienceDirect

databases, all recognized publications with a notable MaaS-focus could be analysed in this study. Currently, in June 2018, we can identify the early scientific findings related to Mobility as a Service, and the wider scale impacts on mobility and transport system of MaaS, such as:

- MaaS makes the transport system more efficient and helps to recognise and choose the daily mobility options (Strömberg et al., 2016).
- Personalized services enable seamless trip chains by integrating different transport modes (Kamargianni et al., 2016).
- Popularity of private cars is expected to reduce as flexible choices such as car-sharing and on-demand ride-sharing services become more common (Giesecke et al, 2016; Karlsson et al., 2016). Overall, MaaS seems to increase use of sustainable transport modes (Karlsson et al., 2016).
- Sustainable transport modes are expected to become more popular (Karlsson et al., 2016) albeit there is not much discussion of the role of cycling in the MaaS literature.
- New flexible transport modes force conventional public transport to adapt to a more service-oriented system (Hensher, 2017).
- MaaS trials enable great possibilities to get to know and try out new mobility services (Strömberg et al., 2016).
- Public sector has a key role as an enabler of MaaS e.g. by supportive legislation (Ambrosino et al., 2016).

In this study, the findings from current MaaS-focused research were assorted into three groups. As MaaS offerings consist of various transport modes, it is natural that many publications discuss different transport modes and services in MaaS context. Particularly, the role of cars, including e.g. car-sharing, is discussed widely. The role of conventional public transport and its integration to new services are also covered in many ways. Several studies also describe MaaS as a concept and depict its nature. In future, viewpoints of the society, land use, and transport system would be important to be covered more thoroughly in order to understand the aggregate impacts of MaaS. In a holistic approach, the impacts of different sub-issues, e.g. how the different transport modes work together in a MaaS scheme, should be studied. Integrative research is also called for on how automated vehicles will connect to and affect MaaS.

Considering the limitations of this study, we recognise the restricted capability to identify all relevant MaaS-focused scientific publications with Scopus and ScienceDirect databases as the publication channels are diverse. Since new research is continually published, this outlook of the state-of-the-art scientific literature on MaaS should be renewed in the following years to keep the findings up-to-date. As there are also several actors outside the scientific community publishing MaaS-relavant findings, reviewing also other literature, e.g. policy documents, information from MaaS providers, and consultant reports, would complement the outlook of MaaS.

In conclusion, the scientific community has so far quite little knowledge on the actual effects of MaaS schemes. There is a need to analyse mobility data from the MaaS providers, private

companies or in some cases public administration, and study the new paradigm and its implications more deeply. That may be a challenge as private companies' willingness to share the data is not clear. As Giesecke et al. (2016) stated, we also need research about the roles and responsibilities of MaaS stakeholders currently and in future. Furthermore, as more sustainable mobility practices are a possible outcome of MaaS, researchers need to study the decisions and choices related to this issue (Brendel & Mandrella, 2016). As new transport services (e.g. car-sharing and ride-sharing) become more popular these should be included in travel surveys in order to get more detailed data of their use (Frei et al., 2017). The basis of MaaS scheme's design is the mobility data and hence more detailed data and a data collection method, as e.g. Matyas & Kamargianni (2017) described in London's context, are needed.

Today, private car ownership and usage are significant issues in our transport system. MaaS concept, however, aims to change this by encouraging the use of mobility services. It is interesting to find out if the service-oriented system is tempting enough to make people change their mobility patterns and give up car ownership. The results from early MaaS trials (e.g. UbiGo) indicate an increased use of sustainable transport modes. All in all, the role of vehicle ownership and motoring in relation to MaaS is an interesting and justified topic for future research. Households, which do not own cars or with several people but one car, have probably the highest interest towards MaaS at the early stages of MaaS implementation. The role of cycling in a service-oriented system is another topic, which should be studied more widely. As MaaS has the potential to change mobility patterns notably, it will be an interesting topic for further research and scientific publishing.

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