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A critical review of new mobility services for urban transport

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Abstract

The growing pressure on urban passenger transport systems has increased the demand for new and innovative solutions to increase its efficiency. One approach to tackle this challenge has been the slow but steady shift towards shared mobility services (car-, bike-sharing etc.). Building on these new modes and the developments in information and communication technologies, the concept of "Mobility as a Service" (MaaS) has recently come to light and offers convenient door-to-door transport without the need to own a private vehicle. The term Mobility as a Service (MaaS) stands for buying mobility services based on consumer needs instead of buying the means of mobility. In recent years, various MaaS schemes have been arisen around the world. The objective of this paper is to review these newly existing mobility services and develop an index to evaluate the level of mobility integration for each based on the assumption that higher level of integration is more appealing to travellers. The review presented in this paper allows a comparison among the schemes and provides the background and the key points of MaaS systems that the research community could use for designing surveys. It also provides significant insights to transport operators and authorities on the elements they should take into account to apply an attractive MaaS scheme that could effectively shift demand away from private vehicles.

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Keywords: Mobility as a Service; new mobility concepts; mobility integration; index

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1. Introduction

The growing pressure on urban passenger transport systems has increased the demand for new and innovative solutions to increase its efficiency. One approach to tackle this challenge has been the slow but steady shift towards shared mobility services (car-sharing, bike-sharing etc.), especially in combination with traditional public transport so that various transport modes can join together to serve as substitute to private vehicles. Nevertheless, the complexity of using a variety of transport modes (i.e. different payment methods, subscriptions, different mobile applications for each operator, lack of integrated information etc.) discourages many people from taking advantage of them. As such, integrating different transport modes and providing seamless door-to-door mobility is one of the priorities of decision makers and transport authorities. Building on these shared modes and developments in information and communication technologies (ICT), "Mobility as a Service" (MaaS) is one of the novel mobility concepts that could assist in achieving seamless mobility.

The term "Mobility as a Service" stands for buying mobility services as packages based on consumers' needs instead of buying the means of transport. Via "Mobility as a Service" systems consumers can buy mobility services that are provided by the same or different operators by using just one platform and a single payment. MaaS platforms usually provide an intermodal journey planner (providing combinations of different transport modes: car--sharing, car rental, underground, rail, bus, bike-sharing, taxi, etc.), a booking system, easy-payment, and real time information (Kamargianni et al., 2015). MaaS users can use the service either as Pay-As-You-Go or they can purchase mobility packages based on their travel needs.

As MaaS is a new mobility service and its implementation is limited, no previous research has been identified that examines MaaS impact on travel behavior, while at the same time data availability is limited deterring the development of models to assess its effect on travel demand. In doing so, the objective of this paper is to comprehensively review the existing MaaS schemes and develop an index to evaluate the level of mobility integration for each MaaS scheme based on the assumption that higher level of integration is more appealing to travellers. The review presented in this paper allows a comparison among the existing schemes and provides the background and the key points of MaaS systems that the research community should take into account in designing surveys. It also provides significant insights to transport operators and authorities on how to design and apply an attractive MaaS scheme that could potential shift demand away from private vehicles.

2. Overview of Mobility integration

Integrated and seamless mobility, the idea behind Mobility as a Service, has been a vision of future urban transport (Motta et al., 2013; Preston, 2012; Schade et al., 2014). MaaS is based on three main elements that, in conjunction, provide users with seamless intermodal journeys. They are:

- *Ticket & Payment integration*: when one smart card or ticket can be used to access all the modes taking part in the service and one account is charged for the use of those services;
- *Mobility package*: when customers can pre-pay for a specific amount (in time or distance) of a combination of mobility services;
- *ICT integration*: when there is a single application or online interface that can be used to access information about the modes.

To our knowledge, there is no research on the combined effect of these elements on travel behavior and mode choice. As such, we will review literatures on the individual element to support the case of MaaS as a tool promoting sustainable transport choices.

2.1. Ticket and payment integration

Ticket integration is the most basic integration way and usually achieved by smart card technology. Smart cards for public transport exist in a large number of cities worldwide and many of them have shown the popularity among users (Smart Card Alliance, 2003). We hereby review six cases with quantitative evidence of which two cases were world-class metropolis and the other two were in relatively smaller cities.

The Hong Kong Octopus card was launched in 1997. It quickly prevailed within Hong Kong's public transport network by incorporating all major operators (i.e. bus, taxi, subway, train, tram, and ferry services etc.). The statistics showed that the Octopus card allowed travellers to pass through fare collection points 15% to 20% faster.

By 2002, 95% of the "economically active population" in Hong Kong were using the card to access public transport due to its convenience (Smart Card Alliance, 2003). A study by McLysaght et al. (undated) identified an even more astonishing figure that over 3 million Octopus cards were adopted within the first 3 months of its launch, nearly half of Hong Kong's entire population (7 million). The report further found that there had been non-linear proliferation of Octopus cards since 1997 and in average each Hong Kong citizen possessed at least two Octopus cards by 2011.

London's Oyster card gained immediate success after its introduction in 2002 (Smart Card Alliance, 2003). 26,000 cards were issued within a few months. Later statistics proved its success even beyond the original estimate. CUBIC (undated) showed over 29 million Oyster cards were issued since 2003 and its introduction caused a phenomenal growth in public transport use across London. Bus patronage increased by 53% to almost two billion rides per year, while tube and Docklands Light Railway rides have increased by almost 20% and over 100% respectively. An interesting aspect of the Oyster card is that it can now be used to access certain car sharing vehicles (City car club) in the city as well, providing ticketing integration among public transport and car sharing. Unfortunately, no data is available to assess the effect of this on car sharing service demand.

Before the introduction of Carte Orange card in 1975, passengers in Paris had to buy a new ticket every time they changed transport operators. According to statistics, Carte Orange that is accepted by all transport operators in Paris had successfully reversed public transport patronage (-12% between 1945 and 1975) to an overall ridership increase of 33% from 1975 to 1993. The results above come from the report by NEA (2003), which conducted case studies over eight European cities that moved towards ticket integration in public transport. The case of Paris has the most significant effect in terms of increased passenger demand due to smart card introduction, but significant effects can also be observed in other cities such as Manchester, Stockholm, Vienna and Hamburg.

Singapore's well-known transport pass is the EZ-link card, which is an enhanced integrated fare system based upon the previous multimodal magnetic-card system ITS. The most significant improvement was that the new fare system removed the payment barriers among separate operators in the transit network so that travellers could experience seamless transfer without having to exit and re-enter. Such ticket integration was achieved via "apportioned fares between the operators in the backend system on a daily basis based on an agreed formula" as explained in Prakasam (2009). The study stated that commuter throughput doubled at train stations after the introduction of the smart card. Moreover, the success of such ticket integration system has led to the innovation of a further improved system CEPAS in Singapore that enables multi-issuer of an integrated smart card.

Finally, two smaller-scale programs of smart cards also demonstrated its successes in supporting public transport usage (Smart Card Alliance, 2003). The transport authority in Washington introduced a contactless smart card called SmarTrip in 1999 to facilitate public transport within the metropolitan area. In the next four years, more than 360,000 travellers switched from paper tickets to the smart card. By 2003, the sales of SmarTrip remained steady at 6,000 to 8,000 cards per month. A pilot smart card program was launched in San Francisco Bay Area where 7,000 cards were distributed. The smart card TransLink connected buses, light, medium and heavy rails, and ferries. A focus group of users were interviewed after three years, and the results showed that smart card positively affected the frequency of the aforementioned modes (AECOM, 2011; Smart Card Alliance, 2003).

There are also studies explaining why smart card makes public transport more attractive to travellers by identifying the potential benefits. Blythe and Holm (2002) present results from a survey among 160 passengers in Tampere, Finland. During the introduction of Combi-card, which connected local public transport, the respondents were asked to state their perceived advantages of the smart card. The result showed around 90% of respondents felt "the transaction is easier", "the transaction is faster" and "passenger boarding is smoother"; over 70% of respondents felt "it suits regional transport better". Also significant percentage of users agreed with other potential uses of the Combi-card such as buses keeping schedules better and shorter waiting time at bus stops. The results serve as robust evidence for the introduction of smart cards. Cheung (2006) conducted a cost-benefit analysis study commissioned by the Dutch Transport Ministry in order to guide and support a national-wide smart card project in Netherlands. By comparing costs and benefits within 2003 and 2017, the direct benefits to passengers including "reduction in ticket purchase time", "reduction in molestation" and "value of extra mobility" were identified to be extremely significant in terms of the assigned monetary values (i.e. 840 to 970 million of euros).

Nonetheless, although ticket integration and payment integration usually occur simultaneously (i.e. one smart card to access various transport services, and the payments to different transport operators are automatically completed in backstage), special cases do occur where either traveller can buy and pay for different services at one integrated place but there is not a smart card to access those services (only payment integration) or traveller has

a smart card for various accesses but needs to pay separate bills for different services (only ticket integration). A few MaaS schemes that will be reviewed in section 3 belong to the latter case.

2.2. Mobility package integration

A mobility package is a type of mobility tool that allows customers to pre-purchase usage of various modes for a longer period of time as one product. The theory behind all mobility tools is that consumers can use the transport modes with low or even zero marginal costs for a fixed upfront cost. Mobility packaging has been used to increase the patronage of modes that are included in the package. Evidence to support this can be found in the transport pass/season ticket literature (season tickets are mobility packages for public transport modes).

Axhausen et al. (2000) used a 1999 Swiss survey to quantify the inter-relationships among car ownership, season ticket ownership and public transport usage. The results showed that season ticket ownership had a significant positive relationship with public transport usage. Further, Simma and Axhausen (2001) demonstrated that committing to a specific mode by purchasing a mobility tool reduced the usage of other modes. This meant that long term decisions, such as purchasing a seasonal travel pass, influenced short-term travel behavior. Bandoe and Yendeti (2007) examined the impact of transit pass ownership on the daily number of trips made by urban transit in the greater Toronto area. Their results supported the finding of Axhausen et al. (2000) by showing that transit pass ownership was the single most important factor determining transit usage. Lathia and Capra (2011) analyzed travel trends and travellers' behavior using London Oyster card data. The demand for travel card was proved by the data analysis through two angles. 1. Travel card owners would use buses more; 2. Pay as you go travellers who were given capped travel price would travel more. Schad et al. (2005) analyzed the Swiss market where the mobility package included a seasonal transport pass as the examples above, but also included access to car sharing and car rental. The results showed that almost 90% of users in the sample no longer kept their own car and part of the users sold their last car at the same time as they bought a mobility package. If the market potential (i.e. use integrated mobility instead of private vehicle) could be exploited in full, then 15 to 50 million liters of petrol could be saved annually in Switzerland (0.4% to 1.4% of national consumption). In a field experiment with over hundreds of participants, Thøgersen (2009) found the provision of a free monthly travel card led to a doubling of the use of public transportation in the experiment group and the positive effect remained half a year after the intervention. Although the experiment adopted an extreme condition of completely free card, the study still concluded with the insight that subscription transport service, pre-paid by traveller, would attract higher usage due to a number of behavioral factors.

2.3. ICT integration

In general, ICT integration in transport refers to a centralized platform that assembles information of various modes. It is expected to facilitate and support travellers throughout the journey during "pre-trip", "wayside" and "on-board" stages (Eryilmaz et al., 2014; Grotenhuis et al., 2007) by including functions such as journey planning, booking and real-time information. Given the rising trend of integrated mobility, there are a number of recent studies that argue the importance of ICT integration.

Although different studies usually adopt different expressions for ICT integration, they still represent the same idea. Grotenhuis et al. (2007) used the term "integrated multimodal travel information" for ICT integration in public transport and identified passengers' desired quality upon such service via a survey in Netherlands. The results showed that even though "pre-trip" was the favorite stage to use the centralized information platform (i.e. planning a trip), "wayside" and "on-board" stages also highly demanded such services to help travellers "catch the right vehicle en route" and "catch connecting modes" respectively. Finally, apart from the commonly demanded functions, such as journey planning, booking and real-time information in ICT integration, Stopka (2014) presented an interesting and inspiring result. Through a literature study and a focus group interview in Dresden, Germany, the study identified the main user requirements for smartphone platform to support door-to-door mobility in public transport. As expected, travellers demonstrated significant interest towards personalized trip advice by the app, while they expected the app to be smart to offer optimal trip advice based on their personal data. As a result, the variety of functions of "door-to-door" apps had been growing based on users' increasing expectation on the smartness of ICT integration. Table 1 summarizes the key findings of the literature reviewed in this section.

Table 1. Summary of mobility integration literatures.

Authors	Topic	Area	Method	Relevant Insights
Blythe and Holm, 2002	Ticket integration	Tampere, Finland	Survey Statistics	Endorsements for Combi-card regarding "easier transaction", "faster transaction", "smoother boarding" and "better suits regional transport" were observed from overwhelming majority of 160 respondents.
Cheung, 2006	Ticket integration	Netherlands	Cost-benefit analysis	By introducing a national-wide smart card, passengers could benefit from "reduction in ticket purchase", "reduction in molestation" and "value of extra mobility", and the benefits were quantified in monetary values.
NEA, 2003	Payment integration	Paris, France	Case study	By offering free transfers among all operators, Carte Orange in Paris successfully reversed public transport patronage (-12% between 1945 and 1975) to an overall ridership increase of 33% from 1975 to 1993.
Prakasam, 2009	Payment integration	Singapore	Case study	Commuter throughput at train stations doubled as they were able to transfer between different transit networks (separate operators) without having to exit and re-enter.
Grotenhuis et al., 2007	ICT integration	Netherlands	Survey Statistics	Integrated multimodal travel information is desired by travellers all the time in a trip including "pre-trip", "wayside" and "on-board" stages.
Eryilmaz et al., 2014	ICT integration	Rhine-Neckar, Germany	Business model	Intermodal Transport Control Systems would enable efficient collaboration of providers and implement integrated mobility services with simple access for customers. A business model for intermodal information systems that offers services for individual planning, real-time route adjustment and provider collaboration was presented.
Stopka, 2014	ICT integration	Dresden, Germany	Focus group interview	The variety of functions of "door-to-door" apps that support seamless mobility had been growing based on increasing user requirements.
Axhausen et al., 2000	Mobility package integration	Switzerland	Structural equation model	Season ticket ownership has a significant positive relationship with public transport usage.
Lathia and Capra, 2011	Mobility package integration	London, United Kingdom	Trend & user behaviour analysis	1. Travel card owners would use buses more; 2. Pay as you go travellers who were given capped travel price would travel more.
Schad et al., 2005	Mobility package integration	Switzerland	Survey Statistics	Mobility-packages allowed people to manage without a car as far as possible. Nearly 90% of all users in the sample no longer kept their own car. Part of the users sold their last car at the same time as they bought a mobility-package.
Thøgersen, 2009	Mobility package integration	Copenhagen, Denmark	Field experiment	The price promotion (subscription service) led to a doubling of the use of public transportation in the experiment group and the positive effect remained half a year after the intervention.

3. Review of Mobility-as-a-Service schemes

Fifteen MaaS systems around the world have been identified and all of those are in developed countries. There is a high concentration of schemes in Continental Western Europe, with Germany and Netherlands leading the way each with multiple MaaS schemes. They can be classified in terms of different integration levels, i.e. partial integration (scheme partially possesses ticket, payment, and ICT integration), advanced integration without mobility packages (scheme completely possesses ticket, payment, and ICT integration), and advanced integration with mobility packages (scheme completely possesses ticket, payment, ICT integration, and mobility packages).

3.1. Partial integration

The basic level of integration is when a scheme not in full but only partially possesses ticket integration, payment integration and ICT integration. At this level, transport modes are integrated in a way that travellers cannot exploit the full benefit of integrated mobility.

The first case is Cambio, the car-sharing company, cooperates with STIB, the combined mobility operator for public transport as well as bike-sharing and taxi in Brussels, Belgium. Although it is a cooperation scheme with two different operators, ticket integration is observed. A common smart card has been designed for the use of both Cambio and STIB services. However, neither payment nor ICT integration exist under this scheme. Member of Cambio can also enjoy discounts when subscribing to STIB service. This joint service has promoted more usage on public transport by linking Cambio stations to the STIB network.

In Germany, Qixxit integrates national-wide mobility options including rail, urban public transport, car-sharing, car rental, bike-sharing and taxi as well as flight and coach. The way that Qixxit integrates these modes is through a smart app by offering journey planning, booking, real-time information and even personalized trip advice. The centralized booking function is the key feature that differentiates it from journey planning apps and makes it belong to MaaS. Nonetheless, Qixxit only involves ICT integration without any forms of ticket or payment integration.

Another national mobility integration in Germany is Moovel, also a single smartphone platform. It includes public transport, car sharing, car rental, national rail, bike sharing and taxi all provided by separate operators such as Car2go, Nextbike and Deustsche Bahn. Car2go, an external car sharing service provider and the projects main partner, is the key to achieving such deployment. Car2go was the first car sharing system in the world without fixed rental locations, which ensures sufficient flexibility to meet demand. The core of the service is the Moovel mobile application that facilitates intermodal journey planning, booking and payment for all services (except for Nextbike). Even though Car2go and Nextbike accounts need to be linked to Moovel directly by the customer, there is ICT integration. However, there is no ticket integration among the modes.

The last partial integration case is Switchh that offers an app and a smart card to access all transport modes in Hamburg, Germany. Hamburg Transport Association (HVV), responsible for the management of local public transport, is the key operator behind the scheme. The subscription with Switchh must be extended from the subscription with HVV and then customers can use services offered by other operators such as Car2go, StadtRAD (bike-sharing) and Europcar etc. with discount. Although Switchh operates a single card system to open Car2go vehicles, enable borrowing at StadtRAD stations and also work for Europcar service, these different operators do not offer a single invoice that can facilitate payment. Therefore, it still belongs to partial integration like Moovel, even though they have more integrations than the first two single integration schemes.

3.2. Advanced integration

This is the level that most of the MaaS schemes belong to where each fully possesses ticket, payment and ICT integration. Hannovermobil is first introduced in 2004 and then re-launched as Hannovermobil 2.0, which is currently being piloted. It has its core the advanced integration of public transport, car sharing, and taxi, but only has cooperative relationship with long distance rail and car rental operators. Hannovermobil subscribers pay slightly more than their usual public transport pass price to access Stadtmobil car sharing vehicles and get discounts for taxi services operated by Hallo Taxi, car rental by Hertz and long distance rail. Customers receive an integrated mobility bill at the end of each month that includes all basic cost as well as taxi and car sharing usage fees. Long distance rail and Hertz car rental prices are not included in the mobility bill, which is why the integration in only basic between these parties. Further, one card can be used to access public transport and car sharing vehicles, providing ticketing integration between Üstra, the public transport provider, and Statmobil. Finally, ICT integration is currently being developed based on the Hannovermobil pilot scheme that will include a smartphone app with real time information.

EMMA is an integrated personal transport platform in Montpellier, France. TAM, which operates public transport, bike sharing as well as car and bike parks in the city, is the key operator of EMMA. TAM customers can purchase either a monthly or a yearly mobility contracts, including the usage of all services that TAM operates. These mobility contracts are tailored towards different user groups (EMMA Young, EMMA Senior) and differ in their payment structure. As the bike sharing service, Velomagg, and the parking services include hourly rates, these can be paid after usage by cash or direct debit. EMMA also offers an online journey planner containing real-time information and the EMMA card is the single key to access all services. TAM also cooperates with Montpellier's car sharing service Modulauto by offering users Multimodal Subscriptions. For a fixed annual or monthly fee, users have free access to the city's public transport network, car and bike parks and can also borrow Velomagg bicycles and Modulauto cars. The bike and car sharing services have additional hourly usage costs that are not included in the subscription and have to be paid by direct debit. Both EMMA Contacts and Mobility Subscriptions show payment, ticketing and ICT integration. The main difference is that the EMMA contract only includes services that are within the institutionally integrated TAM, while the subscription also includes the partner Modulauto car sharing.

Three similar advanced integration schemes in Netherlands are designed for business travellers, i.e. Mobility Mixx, NS-Business Card and Radiuz Total Mobility. They provide a smart card to access a variety of modes across the country including shared modes, public transports and taxis. The only exception is NS-Business Card does not include car-sharing as a mobility option. For payment integration, single monthly invoice is offered by all three schemes to enable one-time payment for travel expenses on different modes. Nonetheless, there is clear difference in terms of ICT integration. Radiuz Total Mobility provides an app that travellers can use to plan a trip; NS-Business Card, although not with an app, it still has an online interface for the same purpose; whereas Mobility Mixx has neither but it offers a unique call-center service that is reachable by travellers 24/7 for trip planning and booking corresponding modes. Overall, such advance integration has benefited business users with time and costs savings.

A few more MaaS schemes are still under research. Smile in Vienna provides cooperation not only between transport providers (urban public transport, rail, car sharing, bike sharing, car rental, taxi) but also between other interested parties such as software companies, engineers and environmental protection groups. It is an ambitious scheme trying to grow into a prototype of intermodal integrated solution by delivering information, booking and payment through a smarter and more efficient system. It includes ICT integration via the Smile app. Payment integration is also linked to the application, and for services that depend on usage (taxi, rental car, bike, parking etc.) the customer is charged right after usage. Optimod' Lyon is also a scheme in research phase, termed as an intelligent transport system in Lyon. It aims to deliver a seamless urban mobility system to reduce the share of private car. The blueprint of the scheme involves travel information, smart ticketing and an electronic toll system to connect various transport options via one centralized platform. Therefore, ticket, payment and ICT integration are all under its pursuit. The last scheme is BeMobility for Berlin. It has a special focus compared to other MaaS schemes. It aims to incorporate electric and hybrid vehicles into car-sharing service which is then integrated with public transport etc. Similar to Hannovermobil, BeMobility also has 1.0 and 2.0 phase. The 1.0 phase has already been piloted with a result of high volume usage over the integrated clean energy car-sharing service and connected public transport. The 2.0 phase, which is still under research, shows ambition towards advanced integration to develop a smartphone app platform that serves as information, access and payment medium. In other words, if the research can be delivered, BeMobility 2.0 is expected to be a fully integrated scheme in which ticket, payment and ICT are all included.

3.3. Advanced integration with mobility packages

The final group of MaaS schemes is an extension of the previous group. The first example is a very unique business model and the only fully institutionally integrated service that multiple modes are owned and operated by one company. This service is SHIFT, initiated in 2013 in Las Vegas. It provides services including shuttle buses, bike sharing, car rental, car sharing as well as a valet service. It does this by owning all of the vehicles in its fleet and not by partnering with other service providers. SHIFT is ICT integrated: the user chooses the destination in the journey planning tool and the SHIFT app will make a choice of transport modes for the user. SHIFT also provides a variety of membership levels each with a designated amount of trip time each month. One minute of travel time on bikes, cars or SHIFT's Valet+ service equals one minute of trip time. As monthly trip time is determined to for total usage, customers have the flexibility to divide up the time among the services in a way that best suits their lifestyle. These pre-paid monthly packages allow customers to pay for all their usage beforehand at once. Of course if the customer runs out of trip time, they can buy it a la carte. SHIFT is unique in its complete institutional integration and its mobility packages provide a new business model compared to the previous projects. In addition, most of the cars owned by SHIFT are electric powered, which has shown a firm movement towards sustainable transport.

Ubigo is a project piloted by GO: SMART. It was tested in the city of Gotherburg, Sweden in 2012 with 70 households and its team is now working on launching it on a larger scale. The project involves the cooperation between Vasttrafik public transport operator, Sunfleet car sharing, Hertz car rental, TaxiKurir taxi and JCDecaux bike sharing. The ICT, payment and ticket integrated service combines everything into one application – even the cars can be opened and access with the app. Households subscribe for prepaid tailored monthly packages determined in time or distance for each mode separately. For example, public transport is determined as days in one or more zones, car sharing, as hours, car rental as days and taxi as distance. The household creates their packages based on their needs as a household as a whole and the price of the package is cheaper than the same amount of service would be on its own. During each journey planning, the user makes their own travel decision on transport modes based on their monthly packages. If the subscription runs empty, additional trips are billed after. Further, electric cars and bikes are available and the user can get bonus points for such sustainable choices.

The final example is the Helsinki Model that advertises itself as the first Mobility as a Service project. Although it is in its initial stages it is expected to be fully applied by 2025. First proposed by Heikkilä (2014), the Helsinki Model discovers a way to reorganize the personal transport sector and to create a door-to-door mobility service. The project brings together 23 partners including a variety of research organizations, ITC and transport companies besides the transport operators. It aims at an open market model based on brand cooperation. Even though the project is not yet operational, it is projected to provide users with pre-purchasable and pre-constructed mobility packages. Each package will be tailored towards a specific socio-demographic group such as families, commuters or businesses. ICT, ticketing and payment integration are at the heart of the project. One interesting element of this project is that besides the modes included in the above-mentioned projects, it also plans on including on-demand transport services. These on-demand services are already being tested via Kutsuplus, the city's on demand bus service, which responds to the real time needs of customers. Table 2 presents an overview of the MaaS schemes presented in this section. It includes the area they operate, the integration type and the modes that are included.

Table 2. Summary of MaaS schemes.

Scheme	Area	Integration Type*				Modes
		1	2	3	4	
STIB+Cambio	Brussels	X				car-sharing, rail, urban public transport, taxi
Qixxit	Germany			X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi + flight, coach
Moovel	Germany		X	X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi
Switchh	Hamburg	X		X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi + ferry
Hannovermobil	Hannover	X	X	X		car-sharing, car rental, rail, urban public transport, taxi
EMMA	Montpellier	X	X	X		bike-sharing, car-sharing, rail, urban public transport
Mobility Mixx	Netherlands	X	X	X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi
NS-Business Card	Netherlands	X	X	X		bike-sharing, car rental, rail, urban public transport, taxi
Radiuz Total Mobility	Netherlands	X	X	X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi
Smile**	Vienna	X	X	X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi
Optimod' Lyon**	Lyon	X	X	X		bike-sharing, car-sharing, car rental, rail, urban public transport, taxi + flight, freight transport
BeMobility**	Berlin	X	X	X		bike-sharing, car-sharing, rail, urban public transport, taxi
SHIFT	Las Vegas	X	X	X	X	bike-sharing, car-sharing, car rental, urban public transport
UbiGo	Gothenburg	X	X	X	X	bike-sharing, car-sharing, car rental, urban public transport
Helsinki Model**	Helsinki	X	X	X	X	bike-sharing, car-sharing, car rental, rail, urban public transport, taxi + on demand transport

*1: Ticket integration, 2: Payment integration, 3: ICT integration, 4: Mobility package integration **In research phase

4. MaaS integration index

The three general categories of mobility integration however cannot reveal the difference of MaaS schemes in the same category. Thus, we further developed an index to allow the comparison between each individual scheme.

We use the four types of integration as basis by scoring each type separately and then adding up to have a total score that represents the integration level. For ticket integration, we measure it by the number of modes that can be accessed via a single ticket and six most commonly observed modes, i.e. bike-sharing, car-sharing, car rental, rail, urban public transport and taxi are included. ICT integration can include functions of journey planning, booking, real-time information and even personalized trip advice. Here, we measure it by considering two separate functions: 1. journey planning, and 2. booking function as the two determinants of integration level since the former only represents information integration whereas the latter requires even further integration which may need to assemble different transport operators' booking system into a centralized platform. At last, mobility package integration is measured by its presence. The detailed scoring framework is described below:

- *TI score: for ticket integration, "1" score for each mode included;*
- *PI score: for payment integration, "1" score if payment integration exists;*
- *JP score: for ICT integration, "1" score if journey planning function exists;*
- *B score: for ICT integration, "1" score if booking function exists;*
- *MI score: for mobility package integration, "1" score if mobility package integration exists.*

In Table 3, we can see a rank of these MaaS schemes in terms of total score. Higher total score implies higher level of mobility integration. The Helsinki Model is identified to lead the rank due to the variety of modes it intends to include with a single ticket and a complete integration with regards to payment, ICT and mobility packages. The schemes with a total score of 9 are also considered to have an extremely high integration level. The only missing element (except the UbiGo case) is the lack of mobility package service. Next, among the schemes with score 8, SHIFT is a special case which has a complete possession over payment, ICT and mobility package integration. However, since SHIFT operates its own fleet, the number of modes it includes is greatly disadvantaged compared to other schemes with score 8. The score 7 is the lowest for advance integration schemes. Hannovermobil, EMMA and NS-Business Card suffer from both less number of modes and missing integration types. The three schemes at bottom all belong to partial integration. Moovel and Qixxit do not have a single ticket to access modes whereas STIB+Cambio does not involve any other integration types except a common smart card as ticket integration.

Table 3. MaaS integration index.

Scheme	TI Score	PI Score	JP Score	B Score	MI Score	Total Score
Helsinki Model	6 (bike-sharing, car-sharing, car rental, rail, urban public transport, taxi)	1	1	1	1	**10**
UbiGo	5 (bike-sharing, car-sharing, car rental, urban public transport, taxi)	1	1	1	1	**9**
Smile	6 (bike-sharing, car-sharing, car rental, rail, urban public transport, taxi)	1	1	1	0	**9**
Optimod' Lyon	6 (bike-sharing, car-sharing, car rental, rail, urban public transport, taxi)	1	1	1	0	**9**
Mobility Mixx	6 (bike-sharing, car-sharing, car rental, rail, urban public transport, taxi)	1	1	1	0	**9**
SHIFT	4 (bike-sharing, car-sharing, car rental, urban public transport)	1	1	1	1	**8**
BeMobility	5 (bike-sharing, car-sharing, rail, urban public transport, taxi)	1	1	1	0	**8**
Radiuz Total Mobility	6 (bike-sharing, car-sharing, car rental, rail, urban public transport, taxi)	1	1	0	0	**8**
Switchh	6 (bike-sharing, car-sharing, car rental, rail, urban public transport, taxi)	0	1	1	0	**8**
Hannovermobil	5 (car-sharing, car rental, rail, urban public transport, taxi)	1	1	0	0	**7**
EMMA	4 (bike-sharing, car-sharing, rail, urban public transport)	1	1	1	0	**7**
NS-Business	5 (bike-sharing, car rental, rail, urban public transport, taxi)	1	1	0	0	**7**
STIB+Cambio	4 (car-sharing, rail, urban public transport, taxi)	0	0	0	0	**4**
Moovel	0	1	1	1	0	**3**
Qixxit	0	0	1	1	0	**2**

In general, the rank result is consistent with the classification of the "general levels" that the schemes belong to advanced integration with mobility packages have top ranks followed by the schemes in advanced integration and partial integration. However, SHIFT and Switchh are two notable cases where the former ranks surprisingly lower and the latter ranks surprisingly higher compared to their positions in the classification of the "general levels".

Nonetheless, the methodology used to develop such grading system is very basic. It is a fresh attempt in transport research community trying to find out a way that can better study the existing MaaS schemes. More sophisticated methods are expected by future works when more data of these schemes become available.

5. Conclusions

MaaS is a newly emerging concept involved with mobility integration. We reviewed the existing MaaS schemes around the world by using ticket integration, payment integration, ICT integration and mobility package integration as criteria and compared individual schemes by developing a mobility integration index.

We assumed higher level of mobility integration is more appealing to travellers and the reviewed literatures proved that the four integration sub-types did positively affect travellers' demand. Although the scope of this paper is limited to a comparison of MaaS schemes, the findings provide the background and the key points of MaaS systems that the research community could use for designing surveys. It also provides significant insights to transport operators and authorities on the elements they should take into account to apply an attractive MaaS scheme that could effectively shift demand away from private vehicles. In particular, researchers and transport planners who deal with MaaS systems should pay attention on how to integrate different transport operators and provide their services as one product. The investigation is needed for the revenue allocation to each transport operator participating in a MaaS scheme (a revenue management model is proposed in Kamargianni et al., 2015). Researchers who deal with the demand side should include in their research not only how a MaaS system as a whole affects travel behavior and car-ownership, but also how each component of a MaaS system (intermodal journey planner, payment methods, booking system, real time information, mobility packages) impacts the demand for this service. In doing so, they can generate insights about the architecture and the user-friendly design of MaaS apps that in turn could increase the intention to use this service. In addition, willingness to pay for MaaS subscription and willingness to pay for buying a package (either as pay-as-you-go or a monthly/annually package) should also be defined.

To conclude, MaaS is a promising mobility solution and is expected to have significant contribution to future urban mobility reform. Future research includes the collection of personal trip diary and stated preference data about MaaS purchase in order to develop models that could be used by MaaS platforms to provide customized mobility packages to MaaS-users.

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