PRACE NAUKOWE UNIWERSYTETU EKONOMICZNEGO WE WROCŁAWIU
RESEARCH PAPERS OF WROCLAW UNIVERSITY OF ECONOMICS AND BUSINESS

2019, vol. 63, nr 10

ISSN 1899-3192
e-ISSN 2392-0041

Aleksandra Koźlak
University of Gdansk, Faculty of Economics
e-mail: aleksandra.kozlak@ug.edu.pl
ORCID: 0000-0003-4127-6911

Barbara Pawłowska
University of Gdansk, Faculty of Economics
e-mail: barbara.pawlowska@ug.edu.pl
ORCID: 0000-0003-4846-6291

MOBILITY-AS-A-SERVICE FOR IMPROVING MOBILITY IN SMART CITIES – A COMPARATIVE ANALYSIS OF SELECTED CITIES

MOBILITY-AS-A-SERVICE JAKO ROZWIĄZANIE USPRAWNIAJĄCE MOBILNOŚĆ W INTELIGENTNYCH MIASTACH – ANALIZA PORÓWNAWCZA WYBRANYCH MIAST

DOI: 10.15611/pn.2019.10.03
JEL Classification: O18, R11, R41, R58

Summary: The smart city concept has been growing in importance in the research activities worldwide as a direction in the development of modern cities. Mobility-as-a-Service (MaaS) solutions are quite a new transport concept introduced in a small number of cities usually in the pilot phase. The main purpose of the article is to explore the interactions and complementarity of these concepts. This paper analyses how MaaS can support progress in achieving smart mobility, and thus the idea of a smart city. It has the potential to improve the use of assets and contributes to a reduction in the number of passenger cars in congested cities. The research methodology includes a literature review and a deductive research method. The research has shown that cities having high indexes of 'smartness' are more likely to implement technologically advanced ICT solutions in transport systems and both these concepts (smart city and Mobility-as-a-Service) are important for the future of cities making them more sustainable and providing a higher quality of life for residents and visitors. The results of this study can be useful for policy makers, especially at local and regional levels.

Keywords: smart city, smart mobility, Mobility-as-a-Service, MaaS.

Streszczenie: Koncepcja inteligentnego miasta jako kierunek rozwoju nowoczesnych miast zyskuje na znaczeniu jako przedmiot badań naukowych. *Mobility-as-a-Service* to nowa koncepcja organizacji transportu, wprowadzona w niewielkiej liczbie miast, mogąca poprawić wykorzystanie zasobów, zmniejszyć udział samochodów osobowych w przewozach i poziom kongestii. Głównym celem artykułu było przedstawienie badań nad interakcjami i komplementarnością tych dwóch koncepcji. W pracy wykorzystano przegląd literatury i wnioskowanie metodą dedukcji. Wykazano, jak MaaS może wspomagać osiągnięcie inteligentnej mobilności i celów inteligentnego miasta. Badanie empiryczne dowiodło, iż miasta mające wysokie wskaźniki w rankingu inteligentnych miast wykazują większe skłonności do wdrażania zaawansowanych technologicznie rozwiązań zaliczanych do MaaS. Obie te koncepcje (*smart city* i *Mobility-as-a-Service*) są istotne dla miast, aby rozwijały się w sposób zrównoważony i zapewniały wysoką jakość życia mieszkańcom.

Słowa kluczowe: *smart city*, inteligentne miasta, mobilność, *Mobility-as-a-Service*, MaaS.

1. Introduction

The 21st century is characterized by the continuous development of cities and the deepening process of urbanization. According to the Population Division of the Department of Economic and Social Affairs of the United Nations, nowadays 55% of the world's population live in urban areas, a proportion that is expected to increase up to 68% by 2050. The urban population of the world has grown rapidly from 751 million in 1950 up to 4.2 billion in 2018 (UN DESA, 2018). Europe is one of the most urbanized continents. In the European Union almost 70% of the population live in urban areas and the trends in this respect are growing. Undoubtedly, as the world continues to urbanize, sustainable development depends increasingly on the successful management of urban growth. Innovative tools are needed to improve the life of both urban and rural dwellers. Well-managed urbanization, informed by an understanding of population trends in the long run, can help to maximize the benefits of agglomeration while minimizing environmental degradation and other potential adverse impacts of the growing number of city dwellers.

The concept of a smart city as a progressive city of the future assumes sustainable urban development based on innovative technologies, the application of which is aimed at increasing the functionality of cities by economic, social and ecological management. Smart cities are a concept that involves the interaction of residents, local authorities, entrepreneurs and other institutions at all stages of their functioning. The main objective of this idea is to strive for using the available space and resources in the most efficient way, with the support of the technology and direct activity of residents. Hence, it is said that a measure of a city's smartness is the local economy structure, and the level of solutions supporting mobility and resource management, including environmental resources, and it is the conscientious and active residents that are the key to success in implementing the idea.

Mobility is one of the most difficult challenges for cities to become more sustainable, mainly due to the constantly growing congestion. Sustainable urban development requires an efficient transport system. Mobility-as-a-Service (MaaS) is one of the solutions that may help to overcome the existing problems. The main theoretical purpose of the article is to explore how the concept of Mobility-as-a--Service can support progress in achieving smart mobility, and thus, progress in the implementation of the idea of a smart city. The empirical goal of the research is to examine whether the implementation of MaaS systems is related to city smartness indicators. The methodology of the research includes a literature review and a deductive research method. The analysis of smart city indicators and sub-indicators of smart mobility was conducted on the basis of the European Smart City Model (TUWIEN, 2015).

2. Methodology

The research methodology is primarily based on a review of literature. A conceptual literature review was conducted to overview, criticize and synthesize data about the research topics using the academic and scientific databases: Scopus, Web of Science, and EBSCO. The study synthesized exploratory keywords aimed at mapping key concepts, types of evidence and gaps in research by systematically searching, selecting and synthesizing the existing knowledge. English language keywords such as 'smart city', 'smart mobility', 'Mobility-as-a-Service, 'MaaS' and keyword combinations: 'smart city + Mobility-as-a-Service', 'smart city + MaaS', 'smart city + smart mobility' were searched in the title, keywords or abstracts of publications. The search was conducted in April 2019.

Articles published before 2005 were filtered and articles discussing technical aspects were omitted to better focus the review. Overall, more than 5000 publications related to a smart city were identified, however, there were only 146 publications related to 'Mobility-as-a-Service' and 17 concerning a combination of 'smart city + Mobility-as-a-Service'. Special attention was directed to the frequently cited literature, showing the main trends of research.

Once the literature was compiled, publications were then analysed to identify those presenting smart city and mobility as service concepts as well as their interrelations, using strategic and critical reading methods. This original compilation included the most relevant published articles and books in the literature over the last few years. Terms and concepts related to smart city, Mobility-as-a-Service, and shared mobility were summarized and presented in the discussion section, were then identified and analysed from this set of publications. The existing terminology related to smart city, Mobility-as-a-Service, and also the topology of MaaS were also identified as part of the review process.

All this, collectively, was used to compile the research on interactions and complementarity between MaaS systems and the smart mobility/smart city concept. On the basis of this study, the authors attempted to determine the influence of MaaS implementation on smart mobility factors (indicators).

The empirical study consisted in analysis of indicators from the assessment of smart cities provided by the Vienna University of Technology (TUWIEN). The analysis concerned cities which implemented MaaS and the results were compared with the results of other cities in the ranking.

3. Smart city concept and six smart components

The complexity of social, economic, spatial and environmental issues typical for cities and urban areas and the dynamics of these changes in these areas force urban communities to seek more efficient and effective methods for managing urban affairs. Many city development models were produced in line with the idea of sustainable development, technological revolution and forming a knowledge-based economy (Pawłowska, 2018).

The concept of a smart city appeared in 1992 to signify the turn in urban development towards technology, innovation, and globalization (Gibson, Kozmetsky, and Smilor, 1992). There is no single, generally accepted definition of a smart city. Depending on the expert's specialization and the purpose of creating such a definition, each expert engaged with smart cities focuses on different aspects of the city's 'intelligence'. The smart city concept is commonly used in different nomenclatures and contexts and with different meanings. Many publications define the concept of smart cities (Albino, Berardi, and Dangelico, 2015; Chourabi et al., 2012; Komninos, 2015; Marolla, 2016; Mosannenzadeh and Vettorato, 2014; Nam and Pardo, 2011; Szelągowska, 2017), pointing to changes that have occurred in them as a result of the development of the concept. It should be taken into consideration that examples of smart cities come in many variants, sizes and types. This is because the smart city idea is relatively new and evolving, and the concept is very broad (Szczech-Pietkiewicz, 2015). Every city is unique, with its own historical development path, current characteristics and future dynamics.

One of the most frequently cited scientific definitions describes a smart city as one "in which ICT are widely and equally used by business, administration, community and ordinary people" (Hollands, 2008). The Shanghai Manual, a UN guide for sustainable urban development in the 21st century, identifies smart cities as "using a combined (digital) infrastructure to improve economic and political efficiency and enable better social, cultural and urban development" (UN Habitat, 2010).

In recent studies published over a period of ten years, it is emphasized that discussion on a smart city should focus not only on the technological aspects and the technical infrastructure, but also on people, learning and knowledge, and how to improve the dialogue between residents and the authorities (Caragliu, del Bo, and Nijkamp 2011; Harrison et al., 2010; Komninos, 2015; Kourtit and Nijkamp, 2012; Song et al., 2017]. A city is first of all a community of people, hence, social participation in the decisions concerning cities is a key factor towards their development.

The literature on the subject lists six dimensions making up the concept of a smart city. The specific components are presented in Table 1.

Table 1. Smart City components

Component	Description	Related aspect of urban life
Smart Economy	Cities should demonstrate high productivity, a climate of innovation and flexibility of the labour market.	Industry
Smart Mobility	Smart mobility means modern transport and logistics systems using ICT to enhance their integrity with the environment and enable people and goods to move around in a safe, user and environment friendly manner as well as in an efficient and cost-effective way.	Logistics & infrastructures
Smart Environment	A city optimizing energy consumption, *inter alia*, through the use of renewable energy sources, carrying out activities aimed at reducing emissions of pollution to the environment where the resource management is based on the principle of sustainable development.	Efficiency & sustainability
Smart People	The initiators of changes in cities should be residents who, with the appropriate technical support, are able to prevent excessive energy consumption, environmental pollution and strive for improving the quality of life.	Education
Smart Living	The city provides its residents with a friendly environment by ensuring wide access to public services, the technical and social infrastructure, a high level of security and, thanks to the appropriate cultural and entertainment on offer, care for the environment and green areas.	Security & quality
Smart Governance	Development in this aspect requires the creation of an appropriate city management system, developing procedures requiring cooperation of local authorities and other city users, and the use of modern technologies in the functioning of the city.	e-democracy

Source: own work based on (EEA, 2015; Lombardi, Giordano, Farouh, and Yousef, 2012).

In practice all the above mentioned contemporary smart city components are mutually integrated with one another, despite the fact that they concern various sectors and aspects of life. The smart city model in the original understanding, the so-called Smart City 1.0, assumed only a wider use of modern technologies in cities, and the main initiators of activities were companies and representatives of the ICT sector. The next phase of smart city modelling, Smart City 2.0, assumed the greater participation of decision-makers and local authorities in the selection of the place of application of modern technologies. However, the most up-to-date and popular smart city concept – Smart City 3.0 – assumes the active participation of city dwellers in creating and using intelligent solutions in all these areas in order to adjust them to the actual needs of residents (Cohen, 2015).

4. The Mobility-as-a-Service concept – literature review

Sustainable urban development and the implementation of the smart city idea require efficient transport operations. However, transport problems in cities, mainly due to congestion, are increasing more and more rapidly. High expectations are associated with the implementation of modern technologies, which could increase the attractiveness of alternative means of transport in relation to private car ownership. Information and Communication Technologies (ICT) have great potential because they can increase the integration of various transport modes and encourage people to use them more often.

Mobility-as-a-Service may be a key solution to solve the problem of urban mobility in a smart manner. MaaS is a recent innovative transport concept which emerged due to the increasing number of transport services offered in cities, and the advancements in technology and ICT. New transport possibilities relate to the expansion of the sharing economy and shared mobility services (car-sharing, bike-sharing etc.) as well as on-demand services. Recently, shared mobility has played a significant role in redefining the mobility patterns, modal decision making, and mobility behaviours. Burrows, Bradburn and Cohen (2015) argue that Mobility-as-a-Service is one of the main 'disruptions' occurring in the transport sector.

The concept of Mobility-as-a-Service was originally introduced in Finland and defined in one of the first studies on MaaS (Heikkilä, 2014) as a system in which a comprehensive range of mobility services are provided to customers by mobility operators. In more recent studies, Mobility-as-a-Service is defined as multimodal and sustainable mobility services addressing the transport needs of customers by integrating planning and payment on a one-stop-shop principle. MaaS comprises three main components that enable and provide integrated mobility services to end-users: shared mobility, booking/ticketing and multimodal traveller information (Eckhardt et al., 2017). The above definitions focus on organisational and technical components of a MaaS system, such as 'one-stop shop', 'one interface', 'mobility operator', a 'comprehensive' range of modes.

Cole (2018) defined MaaS looking at the whole transportation network and taking into account the wider implications for the concept of the community: Mobility-as-a-Service is a combination of public and private transportation services within a given regional environment that provides holistic, optimal and people-centred travel options, to enable end-to-end journeys paid for by the user as a single charge, and which aim to achieve key public equity objectives.

A wide overview of MaaS definitions was provided by Sochor et al. (2018) and Jittrapirom et al. (2017). The definitions and descriptions of Mobility-as-a-Service cover some common and some different central components related but not limited to technology, organisation, function, value offering, and society. However, the core elements of various definitions can be pointed out: integration of transport services, information, payment and ticketing and fulfilment of the user's transport needs as the main objective.

Mobility-as-a-Service is frequently described in terms of the following types of integration: information and service, bundles, ticketing and payment (Jittrapirom et al., 2017; Kamargianni, Li, Matyas, and Schäfer, 2016; König, Eckhardt, Aapaoja, Sochor, and Karlsson, 2016; Sochor, Arby, Karlsson, and Sarasini, 2018). In comparison to the traditional concept of mobility integration, a new component is bundle integration which is aimed to simplify access to mobility and to ensure the best use of all transport modes. Bundle integration means that a user buying a mobility package or a bundle at a fixed price purchases predefined sets of credits for a combination of modes (Durand, Harms, Hoogendoorn-Lanser, and Zijlstra, 2018).

Kamargianni et al. [2016] classified MaaS systems regarding different integration levels: 1) partial integration (partially integrated ticket, payment, and ICT); (2) advanced integration (completely integrated ticket, payment, and ICT); and (3) advanced integration with mobility packages. Sochor et al. (2018) developed a typo-logy of MaaS schemes distinguishing four integration levels and a basic level without integration (Figure 1).

Fig. 1. Topology of Mobility-as-a-Service including levels and examples

Source: (Sochor et al., 2018).

The levels are not quite dependent on each other because it is possible that a system can reach Level 3 without fully completing Level 1, for example, Level 5 – Integration of societal goals – refers to goals such as congestion mitigation and urban planning. Durand et al. (2018) proposed that Level 2 should be considered as a lower level in terms of MaaS, thus, integration of planning trips, booking and payment is necessary to call a system MaaS. It is important to specify what exactly MaaS is, considering the fact that some new initiatives claim to offer MaaS, whereas they provide travel information only.

The benefits of the MaaS concept can be analysed from different perspectives: users, transport operators (business), public sector (achievement of social, economic and environmental goals). However, there is not enough quantifiable evidence on the costs and benefits of MaaS, and how it influences the travel patterns and behaviour of users, or if it supports the policy goals. Early research from pilot schemes appears to confirm the benefits of MaaS, particularly if the level of service and convenience of the platform encourages transport users to reduce the use of private cars in favour of public and shared modes of transport (Transport Committee, 2018).

The main user benefits result from well-functioning transport services and easy access to mobility, as well as from personalised services tailored to the diverse needs of users. Better access to the transport service improves access to different types of activity such as employment, education, health care, shopping, entertainment, etc. Additionally, the use of active modes of travel such as walking and cycling has a positive influence on the physical health of users.

The widest list of benefits concerns the public sector and the achievement of economic, social and environmental goals. From the point of view of the transport policy, the most important goal is to form an effective and sustainable transport system. The aggregated data from the MaaS application helps to manage the travel demand and the transport infrastructure in a better way and enables the more efficient allocation of resources. Another significant factor is also more efficient traffic incident management. Environmental benefits mainly come from reduced road congestion and improved air quality because of decreased car use.

5. Mobility-as-a-Service as a factor supporting smart mobility – a comparative analysis of selected cities

Smart mobility is a key component of a smart city. Urban mobility is an important determinant of the city's economic function and productivity. Nowadays it is important to make the transport system more sustainable as transport is a source of negative external effects and congestion and the smart mobility concept is one of the most promising topics, as it could bring greater benefits in terms of the quality of life, economy and environment. Mobility and its impact on other dimensions of the smart city, such as the economy, living standards and environment, make this issue essential for citizens and local governments. The main challenge is shaping high-performance services to change the mobility behaviour towards a more sustainable transport system instead of using private cars.

Benevolo, Dameri and D'Auria (2016), stated that smart mobility can be defined as 'a set of coordinated actions addressed at improving the efficiency, the effectiveness and the environmental sustainability of cities'. The use of the term 'smart mobility' generally refers to the deployment of intelligent, ICT-based solutions, but it also covers transport preferences and the behaviour of residents.

Mobile technology and public policy continue to evolve to integrate public transport with shared mobility. The mobility management can support new and innovative solutions to increase the urban transport efficiency and one approach to tackle this challenge has been a shift towards shared mobility services. As a multimodal platform for sustainable mobility services, the Mobility-as-a-Service concept has a huge potential to support smart mobility.

Increasingly more cities all over the world are seeking possibilities to support the establishment of a new multi-modal transport system in their area. There are currently many examples of MaaS implementation in European cities, varying in nature and scale. MaaS is an evolving concept with new services constantly being added. A high concentration of MaaS schemes exists in Western Europe and in the Scandinavian countries. Table 2 contains an overview of selected MaaS initiatives in Europe (fully implemented or in the pilot phase). This overview is not comprehensive, and many initiatives are currently being developed and should emerge in the coming years.

Most cities have journey planners, but the next step is to include both public and private transport, as well as booking and payments functions. The majority of the reviewed Mobility-as-a-Service systems have reached Level 2 of integration. They have integrated ICT, although ticketing and payment are not necessarily integrated yet. Tickets must be booked and paid for separately, which is, e.g., the case for Moovel in Germany, myCicero in Italy, Tuup in Finland and NaviGoGo in Scotland. Ticketing integration only means that travellers have a single ticket (e.g. smart card) for accessing all various services, but separate fees must be paid for such services. Partial payment integration is provided in Hannovermobil in Germany, and EMMA in France (Durand et al., 2018). The most advanced applications where MaaS bundles are used, are Whim and UbiGo (Level 3). In these systems, personalized combinations and amounts of public transport, carsharing, bike-sharing and car rentals are offered in prepaid tailored monthly plans. Whim is the first commercial MaaS product, which is fully operational in Helsinki (Finland) and is expanded to Antwerp (Belgium), Amsterdam (the Netherlands) and the West Midlands (the UK). Whim users can choose a monthly mobility subscription or pay as they go using a payment account linked to the service (Durand et al., 2018). The UbiGo app combines public transport, car sharing, rental car services and taxi as one intermodal on-demand mobility service. It is based on a flexible monthly subscription with an account that is shared among all members of a household. It can be modified on a monthly basis and includes the possibility of topping up and receiving a roll-over credit (König et al., 2016).

Table 3 includes an overview of smart city components in the seven cities analysed in Table 2 – Helsinki, Antwerp, Amsterdam, Gothenburg, Stockholm, Hannover, and Stuttgart. The smart mobility component for selected cities is also presented in detail.

Table 3 presents indexes and sub-indexes of individual smart city components for selected cities. These indexes were calculated according to the methodology developed by the Vienna University of Technology for the European Smart City Model. The TUWIEN team has worked on the issue of smart cities since 2007. The model provides an integrative approach to profile and benchmark European cities; 90 European cities with a population of 0.3-1.0 million were included in the European Smart City ranking of 2015. Figure 2 shows the seven cities analysed in the MaaS context included in the 2015 ranking.

Table 2. Overview of selected MaaS initiatives in Europe

MaaS system	City	Integration level	Integration type				Modes of transport
			ticket	payment	ICT	mobility package	
Whim	Helsinki Antwerp Amsterdam West Midlands	3	X	X	X	X*	urban PT, regional PT, carsharing, car renting, taxi, bike-sharing
UbiGo	Gothenburg Stockholm	3	X	X	X	X	urban PT, carsharing, car renting, taxi, DRT, bike-sharing
Hannover Mobile	Hannover	2	X	X	X		urban PT, regional PT carsharing, taxi
Tuup/Kyyti on demand ride service	Turku	2	X	X	X		urban PT, long-distance buses and trains, domestic flights, ferries, car renting, carsharing, taxi, city bikes and scooters, DRT
WienMobil	Vienna	2	X	X	X		urban PT, carsharing, car renting, taxi, bike-sharing, parking garages, e-loading stations,
EMMA	Montpellier	2	X	X	X		urban PT, rail, carsharing, bike- sharing, parking
Optimod	Lyon	2	X	X	X		urban PT, rail, flights, ferries, car renting, carsharing, taxi, bike-sharing
NaviGoGo	Dundee and North East Fife region (Scotland)	2	X	X	X		urban PT, regional PT, carsharing, taxi
Moovel	Germany (Stuttgart, Hamburg, Karlsruhe)	2		X	X		urban PT, regional PT, rail, carsharing, taxi, bike sharing
myCicero	Italy	2 (partially, payment integrated)	X	X	X		urban PT, regional PT, parking, permit for urban congestion charging zones

* Mobility packages are available only in Helsinki and Antwerp. In other locations there is the ‘pay as you go’ option.
PT – public transport, DRT – demand responsive transport.

Source: own elaboration based on (Durand et al., 2018; Kamargianni et al., 2016) and websites of providers.

Table 3. Characteristics of the selected cities according to Smart City components

Smart component		Amsterdam	Antwerp	Gothenburg	Hannover	Helsinki	Stockholm	Stuttgart
Smart City Index		0.892	0.25	0.899	0.333	0.861	1.106	0.55
Smart Economy		1.624	0.351	0.625	0.344	1.126	1.203	1.063
Smart People		1.029	–0.189	0.899	0.363	1.205	1.052	0.668
Smart Governance		0.63	0.3	1.28	0.139	0.781	1.248	0.128
Smart Environment		0.297	0.358	1.548	0.379	0.8	1.492	0.425
Smart Living		0.506	–0.052	0.629	0.234	0.424	0.985	0.409
Smart Mobility	Average	1.268	0.732	0.415	0.536	0.828	0.656	0.609
	Local transport system	0.608	0.252	0.582	0.282	1.895	2.215	0.216
	(Inter-)national accessibility	7.773	1.264	–0.308	1.302	–0.523	–0.645	1.653
	ICT-Infrastructure	1.88	1.24	0.974	0.498	1.568	0.792	0.498
	Sustainability of the transport system	0.813	0.071	0.412	0.061	0.372	0.262	0.068

Source: own elaboration based on (TUWIEN, 2015).

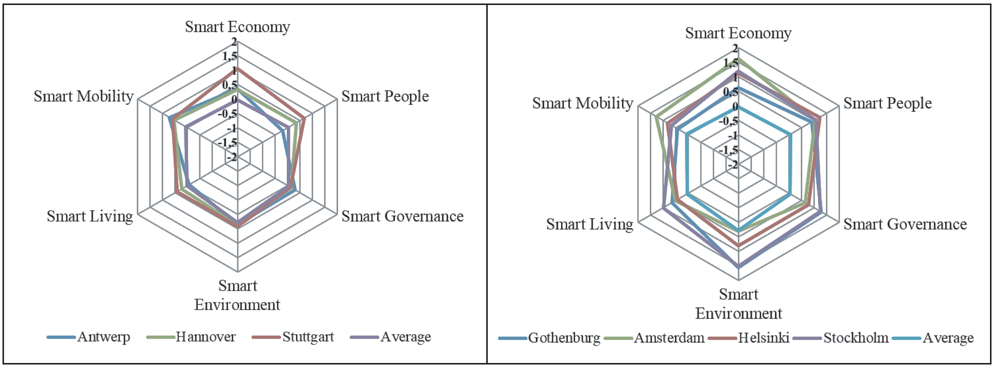

Fig. 2. Comparison of smart city sub-indexes in the seven analysed cities

Source: own elaboration based on (TUWIEN, 2015).

The data presented in Figure 2 shows that the smart mobility sub-index (SM--index) is much higher in all the seven cities than the average index for all the ranked cities, which was 0.068 in 2015. The highest index of 1.268 was in Amsterdam. The SM-index in Helsinki and in Antwerp was 0.828 and 0.732, respectively. In Stockholm and in Stuttgart it was at a level of approximately 0.6 while the lowest SM-index of 0.415 was observed in Gothenburg. Nonetheless, it is considerably higher than the average for the ranked cities. Such a high SM-index results from the modal structure of travelling in the city. For example, in Amsterdam, 38% of trips were made by car, 20% using public transport, 22% by bike, and 20% on foot (European Platform on Mobility Management [EPOMM], 2010). The share of public transport in the remaining six cities was also high: Helsinki – 34%, Stockholm – 35%, Gothenburg – 29%, Stuttgart – 24%, and Hanover – 18%. In Antwerp the share of public transport was only 16%, however, trips by bike accounted for as much as 23%. An analysis of the remaining sub-indexes shows that they are also above the average in the analyzed cities as far as all the ranked cities are concerned. The indexes were exceeded to the highest degree in Amsterdam, but they were also high in Helsinki and Stockholm.

An analysis of the transport solutions in these cities shows that they attach great importance to the use of innovative technologies to support the implementation of the smart city concept. Despite the already high SM-city indexes, these cities continue to improve their transport systems by, among others, implementing the concept of Mobility-as-a-Service. For example, the Amsterdam authorities believe that owning a car becomes less attractive when users can contract mobility services that provide seamless access to public transport, taxi services, shared cars and bikes, shuttle services, parking solutions and easy ways of payment (Amsterdam Economic Board, 2017). Other analyzed cities also use ICT solutions to improve mobility.

New mobility services and business models are changing the urban transport, affecting both the supply and demand sides of the urban mobility market. App-based mobility services such as Mobility-as-a-Service offer new possibilities to expand and complement the existing mobility and can help to balance public and private transport in cities and make the transport system more sustainable and smarter. It has been shown that cities which have introduced (or tested) MaaS solutions are ranked high by TUWIEN. Why is MaaS so important and how could it affect smart mobility indicators? Table 4 contains an assessment of the relationship between MaaS and each smart mobility indicator.

MaaS exerts the strongest influence on the satisfaction of travellers with access to public transport and on its quality. Today public transport is still off-limits for some people and fails to fulfil the needs of others. MaaS increases access to public transport by integration with other modes of travel and by offering simplified ticketing and payment processes, improving passenger experiences in that way. It can encourage the adoption of new travel behaviour patterns. According to Sochor et al. (2016), the personalisation of subscription packages in UbiGo which has increased the satisfaction of users, and better fits the needs of each household played a fundamental role in changing the travel behaviour. MaaS solutions can improve international accessibility, if they take into account not only the urban transport means, but also long-distance transport.

Sustainability of the transport system is particularly significant for a smart city, and the indicators in this area have a substantial share in the total smart mobility rating. Here, MaaS systems affect the share of green mobility and traffic safety rather moderately and indirectly. The majority of MaaS solutions include bike sharing services.

Table 4. Relationships between smart mobility factors and implemented MaaS

Smart mobility factors	Smart mobility indicators	Strength of MaaS influence	Relationship with MaaS (MaaS influence on smart mobility indicators)
Local transport system	Public transport network per inhabitant	0	No relationship
	Satisfaction with access to public transport	++	MaaS increases access to public transport by integration with other modes of travel
	Satisfaction with quality of public transport	++	MaaS affects the subjective perception of the quality of transport and increase satisfaction with the city transport system
(Inter-)national accessibility	International accessibility	+	MaaS app can integrate (inter-)national-wide mobility with the local transport system, mainly in the area of journey planning (e.g. Qixxit in Germany)
ICT--Infrastructure	Computers in households	–	Reverse relationship – quantity of computers and broadband Internet access in households can influence the use of ICT solutions for transport (through a web-interface)
	Broadband internet access in households		
Transport system sustainability	Green mobility share (non-motorized individual traffic)	+	MaaS usually includes bike sharing services
	Traffic safety	+	MaaS improves traffic safety indirectly due to a decrease in the use of private cars
	Use of economical cars	+	MaaS may encourage citizens to carsharing (more and more often, carsharing fleets consist of electric cars)

++ – high influence of MaaS on the smart mobility indicator, + moderate influence of MaaS on the smart mobility indicator, 0 – no relationship between MaaS and the smart mobility indicator, a reverse relationship i.e. the smart mobility factor supports the MaaS performance.

Source: own elaboration.

Bicycle sharing is often referred to as a solution of the "last mile" problem to connect users to public transit networks. In that way, bicycles are used by travellers to a larger extent and their share in commuting increases. For example during the UbiGo trial, there was an increase in both bike and car sharing and a decrease in private vehicle use (Sochor, Karlsson, and Strömberg, 2016). There is only an indirect relationship between the implementation of MaaS and higher traffic safety due to the decrease in the use of private cars. Furthermore, the high quality of route-finding services would improve and enhance the flow of traffic through major corridors of cities.

6. Conclusions

Smart cities around the world are working to ensure mobility as part of the overarching goal to improve the quality of life in places where residents live and work. The importance of transport for a smart city results from its multilateral links with different forms of human activity. Europe's transport system must move towards a more user-friendly, digital and intelligent mobility model. Improving mobility, accessibility and reducing traffic congestion are some of the greatest challenges for smart city governance. The Mobility-as-a-Service concept is central to give an opportunity to reduce some nuisance factors, and cities address these issues because it brings together the various transportation options in a city such as public transport, shared bikes, ride-hailing services, on-demand options and more, and allows citizens to plan their routes, choose the preferred mode of travel and book and pay for everything via one app.

The implementation of Mobility-as-a-Service may positively influence smart mobility indicators in different ways and with varying force (Table 4). MaaS strongly affects the satisfaction of travellers with access to public transport and its quality, which may encourage them to reduce the number of vehicles in households. Reducing vehicle ownership results in a lower demand for parking space, less congestion, increased road safety due to fewer road accidents, and reduced emissions of local pollutants and energy consumption. Further research will be needed to empirically confirm the results of these considerations to support the hypothesis that the implementation of MaaS has an effect on increasing the smart city indexes. Nonetheless, such research will be possible only after a few years of operation of MaaS, when subsequent editions of smart city rankings are published.

MaaS implementation leads not only to smarter mobility, but also affects factors of smart environment (congestion, pollution, sustainable resource management), smart living (better health conditions, better accessibility), and to some extent, smart economy (innovative business models, growth of productivity due to less congestion). This shows the importance of this mobility concept for success in other components of a smart city.

An analysis of indexes and sub-indexes showing the specific components of a smart city showed that these indicators in cities which had implemented Maas systems were at levels significantly above the average in cities analyzed by TUWIEN. This shows that these cities are not content only with what has been achieved but they are pioneers in implementing subsequent technologically advanced solutions. A small number of MaaS systems operating in Europe at least at Level 2 shows that the implementation of such a system is a great challenge for the city. The literature suggests that the key drivers affecting successful implementation of MaaS are (Mulley, Nelson, and Wright, 2018): technology as an enabler to the delivery of the MaaS, widespread availability of modern digital solutions, access to open data (e.g. timetables, real-time location information, user-generated content), provision of interoperable payment systems of transport service providers (e.g. railway operators, taxis, local transport operators, car-sharing) and regulatory reform. The success of MaaS is also dependent upon a shift in transport users' behaviour, from mobility based on private car ownership towards using other modes.

There is no single recipe of how to implement MaaS in cities. Every city is different and has its own local conditions. The problems of a city should be carefully diagnosed, the needs and preferences of residents concerning mobility should be identified and MaaS should be implemented step by step as an urban mobility management tool. The integration of all transport-related information from a variety of sources will provide cities with an insight into their travel patterns, and using AI and machine learning, they will be able to analyse how travel decisions are made and what influences them.

Bibliography

Albino, V., Berardi, U., and Dangelico, R.M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology*, 22(1), 3-21.

Amsterdam Economic Board. (2017). *Amsterdam to pilot Mobility as a Service in 2018*. Retrieved 24.07.2019 from https://www.amsterdameconomicboard.com/en/nieuws/amsterdam-start-2018--mobility-as-a-service

Benevolo, C., Dameri, R.P., and D'Auria, B. (2016). Smart mobility in smart city action taxonomy, ICT intensity and public benefits. In: T. Torre, A.M. Braccini, and R. Spinelli (Eds.), *Empowering Organizations: Enabling Platforms and Artefacts* (pp. 13-28). Springer International Publishing.

Burrows, A., Bradburn, J., and Cohen, T. (2015). *Journeys of the future – introducing Mobility as a Service*. Atkins Global.

Caragliu, A., del Bo, C., and Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology, 18*(2), 65-82.

Chourabi, H., Walker, S., Gil-Garcia, J.R., Mellouli, S., Nahon, K., Pardo, T.A., and Scholl, H.J. (2012). *Understanding smart cities: An integrative framework* (Proceedings of the Annual Hawaii International Conference on System Sciences, pp. 2289-2297).

Cohen, B. (2015). *The 3 generations of smart cites*. Retrieved 20.07.2019 from https://www.fastcompany.com/3047795/the-3-generations-of-smart-cities

Cole, M. (2018). *10 objectives for assessing Mobility as a Service (MaaS)*. GreenBiz. Retrieved 20.07.2019 from https://www.greenbiz.com/article/10-objectives-assessing-mobility-service

Durand, A., Harms, L., Hoogendoorn-Lanser, S., and Zijlstra, T. (2018). *Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review*. KiM Netherlands Institute for Transport Policy Analysis.

Eckhardt, J., Aapaoja, A., Nykänen, L., Sochor, J., Karlsson, M., and König, D. (2017). *Deliverable 2: European MaaS Roadmap 2025* (MAASiFiE project funded by CEDR).

European Environment Agency [EEA]. (2015). *Land systems*. Retrieved 20.07.2019 from https://www.eea.europa.eu/soer-2015/europe/land

European Platform on Mobility Management [EPOMM]. (2019). *TEMS – The EPOMM modal split tool*. Retrieved 23.07.2019 from http://www.epomm.eu/tems/index.phtml

Gibson, D. V., Kozmetsky, G., and Smilor, R.W. (1992). *The technopolis phenomenon: Smart cities, fast systems, global networks*. Rowman & Littlefield.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., and Williams, P. (2010). Foundations for smarter cities. *IBM Journal of Research and Development*, *54*(4), 350-365.

Heikkilä, S. (2014). *Mobility as a Service – a proposal for action for the public administration case Helsinki*. Aalto University.

Hollands, R. G. (2008). Will the real smart city please stand up?. *City*, *12*(3), 303-320.

Jittrapirom, P., Caiati, V., Feneri, A. -M., Ebrahimigharehbaghi, S., González, M.J.A., and Narayan, J. (2017). Mobility as a Service: A critical review of definitions, assessments of schemes, and key challenges, *Urban Planning*, *2*(2), 13-25.

Kamargianni, M., Li, W., Matyas, M., and Schäfer, A. (2016). A critical review of new mobility services for urban transport. *Transportation Research Procedia*, *14*, 3294-3303.

Komninos, N. (2015). *The age of intelligent cities: Smart environments and innovation-for-all*. London: Routledge.

König, D., Eckhardt, J., Aapaoja, A., Sochor, J., and Karlsson, M. (2016). *Delivarable 3: Business and operator models for MaaS* (MAASiFiE project funded by CEDR).

Kourtit, K., and Nijkamp, P., 2012, Smart cities in the innovation age. *Innovation: The European Journal of Social Science Research*, *25*(2), 93-95.

Lombardi, P., Giordano, S., Farouh, H., and Yousef, W. (2012). Modelling the smart city performance. *Innovation: The European Journal of Social Science Research*, *25*(2), 137-149.

Marolla, C. (2016). *Climate Health Risks in Megacities*, CRC Press.

Mosannenzadeh, F., and Vettorato, D. (2014). Defining Smart City. A Conceptual Framework Based on Keyword Analysis. TeMA – Journal of Land Use, Mobility and Environment, *24*(1), 3-27.

Mulley, C., Nelson, J.D., and Wright, S. (2018). Community transport meets Mobility as a Service: On the road to a new flexible future. *Research in Transportation Economics*, *69*, 583-591.

Nam, T., and Pardo, T. A. (2011). *Conceptualizing Smart City with Dimensions of Technology, People, and Institutions* (Proceedings of the 12th Annual International Digital Government Research Conference on Digital Government Innovation in Challenging Times, pp. 282-291).

Pawłowska, B. (2018). Koszty zewnętrzne transportu w Polsce, *Scientific Review Engineering and Environmental Sciences*, *27*(1), 28-41.

Sochor, J., Arby, H., Karlsson, I.C.M., and Sarasini, S. (2018). A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. *Research in Transportation Business & Management*, *27*, 3-14.

Sochor, J., Karlsson, I.C.M., and Strömberg, H. (2016). Trying out Mobility as a Service: Experiences from a field trial and implications for understanding demand. *Transportation Research Record: Journal of the Transportation Research Board*, *2542*(1), 57-64.

Song, H., Srinivasan, R., Sookoor, T., and Jeschke, S. (Eds.). (2017). *Smart cities: foundations, principles, and applications*. Hoboken, NJ, USA: John Wiley & Sons, Inc.

Szczech-Pietkiewicz, E. (2015). Smart city – próba definicji i pomiaru. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, (391), 71-82.

Szelągowska, A. (2017). *Inwestycje w zrównoważonym rozwoju miast*. Warszawa: CeDeWu.

Transport Committee. (2018). *Mobility as a Service, eight reports of session 2017-19*. House of Commons Transport Committee.

TUWIEN. (2015). *European smart cities*. Vienna University of Technology. Retrieved 20.07.2019 from http://www.smart-cities.eu

UN DESA. (2018). *World urbanization prospects: The 2018 revision*. Department of Economic and Social Affairs Of the United Nations.

UN Habitat. (2010). *Shanghai manual – a guide for sustainable urban development in the 21st century*. United Nations.

Utriainen, R., and Pöllänen, M. (2018). Review on Mobility as a Service in scientific publications. *Research in Transportation Business and Management*, (27), 15-23.