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Urban smart mobility in the scientific literature — bibliometric analysis

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ABSTRACT
This article aims at identification of the main trends in scientific literature characterising urban smart mobility, on the basis of bibliometric analysis of articles published in the ISI Web of Science and Scopus databases. The study period was set from 2000 to 2017. Authors used a basic technique of the bibliometric analysis of the scientific literature characterising urban smart mobility with the support of the VOSviewer software. The analysis included the number of publications, citation analysis, research area analysis and the most frequent keywords. The analysis led to taking notice of current research trends dealing with the urban smart mobility. The core of the paper is a theoretical framework of research trends, which was developed through a review of scientific literature. The result of this paper is a map showing the existing relationships between key terms, research areas characterising publications dealing with the urban smart mobility and intelligent transport system (ITS). "Smart city" is probably the most "in vogue", debated and analysed concept among researchers and administrative/governmental representatives from all over the world. This multidimensional concept is mainly based on smart technology structured around few major components: smart mobility, smart environment, smart governance, smart living, and everything that targets the people's wellbeing. This work focuses on a hot topic – mobility because of its significant impact on the environment by pollution as well as living by requiring intelligent transport systems.

KEY WORDS
smart mobility, bibliometric analysis, urban intelligent transport system, urban mobility

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Introduction

This paper tackles an important issue of modern cities, namely, smart mobility, presenting the main challenges and possible solutions as well as the stakeholders involved and responsible for applying these. It presents the developed bibliometric analysis of scientific publications dedicated to smart mobility and presents advantages for different communities: scientific researchers and academia, municipalities and companies.

Contemporary cities must be able to deal with the effects of progressing globalisation trends, processes of integration and urbanisation. The industrial evolution has both benefits (increasing wellbeing) and drawbacks (city crowding). The level of welfare of many families can be measured by the number of owned cars; in many cases, the number more than one. But this means much more traffic which includes the public and heavy goods transport, creating congestion and, finally, air and noise pollution. Also, parking space and other infrastructure problems are the consequence of city crowding. Furthermore, the lack of road infrastructure determines the increasing number of injuries and accidents which reflect in medical costs and economics (Welle et al., 2018).

Since smart mobility is part of the multidimensional concept of a smart city, solutions have to come from multiple directions: municipalities, scientific researchers, environment agencies, transport companies, etc. (Ejdys, Nazarko, Nazarko & Halicka, 2015). Local authorities are becoming increasingly interested in intelligent solutions which help them build the city's competitive advantage and, in effect, attract human capital, business and investors. It should be noted that the number of local governments utilising Intelligent Transport Systems has grown in recent years.

The contribution of our work targets both the scientific community and companies as well as municipalities. For scientific researchers, our bibliometric study will emphasise challenges, solutions and weaknesses, helping them to find science networks working in the smart mobility field for the identification of further potential research partners. Companies will benefit recognising technological trends and global market evolution, of competitor activities, and may forward their in-house research and development activities. The municipalities or funding organisations may use this work to make regional, national or international comparisons of practical solutions regarding intelligent transport systems or to set the timeframe for their implementation.

This paper focuses on publications in the form of scientific articles on urban mobility and intelligent transport systems, which have become an area of discussion and scientific research in recent years. This article aims to make a bibliometric analysis of international literature, namely, scientific articles published in the Web of Science and Scopus databases in years 2000–2017, to identify and take a closer look at current research trends related to the concept of urban smart mobility. The study uses basic techniques of the bibliometric method with the help of the VOSviewer software. In this article, authors identify the main research areas in the literature and propose future research streams in the analysed context.

The structure of the paper is as follows. Sections 1 and 2 describe definitions, challenges and possible solutions regarding the smart mobility. Section 3 presents an overview of the bibliometric methodology, whereas Section 4 illustrates the research results. Finally, the last part concludes the paper and suggests some directions for future work.

1. Literature review

There is extensive literature that describes the basic concepts and assumptions related to smart cities. A smart city has many definitions, but it is also rather frequently identified with such terms as a "digital city", "intelligent city", "creative city" or even a "smart community".

Cities around the world have built a transformative culture around six components characterising a smart city: smart governance, smart mobility, smart environment, smart economy, smart living and smart people. A smart city is often defined as an urban space with complete and advanced infrastructure, intelligent networks and platforms, with millions of sensors used by people and their mobile devices (Yue, Chye & Hoy, 2017). Neirotti et al. (2014) defined a smart city "as an ecosystem that is largely developed through the effective use of technology with the aim of improving the quality of life of citizens achieved through efficient integrated systems and services." A smart city is often defined in the literature as a well performing and forward-looking city described using six characteristics, namely, economy, people, governments, mobility, environment and life, and based on the intelligent combination of capital and the activity of self-decisive, independent and aware residents. Furthermore, a smart city searches for intelligent solutions that help improve the quality of services provided to citizens and identifies those (Romanowski & Lewicki, 2017). A smart city is furthermore used to discuss the use of modern technology in everyday urban life, which besides ICT, includes especially modern transport technologies (Giffinger et al., 2007, p. 10).

Nowadays cities are constantly changing, and new technologies are one of the main factors that led to the emergence of smart cities. There are many examples of smart cities and ideas that fit into the intelligent solutions, which may concern (among other improvements) the transport infrastructure (Romanowski & Lewicki, 2017). Within the current economic period which will last until 2020, the transport infrastructure has become especially challenging in respect to city development and the processes of urbanisation.

In the literature, smart mobility is often presented as one of the main options for more sustainable transport systems (Pinna, Masala & Garau, 2017). Benevolo et al. (2016) state that smart mobility could be perceived as "a set of coordinated actions addressed at improving the efficiency, the effectiveness and the environmental sustainability of cities." The main aspect of smart mobility is connectivity, which along with big data, allows users to transmit all the traffic information in real time while representatives of local governments of cities can simultaneously conduct dynamic management (Pinna, Masala & Garau, 2017). In other words, urban mobility is mostly related to traffic management in real-time, management of passenger transport means, tracking applications and logistics, car park management and car sharing services, and another various smart mobility services (Yue, Chye & Hoy, 2017).

Scientific research conducted in the past confirm that the intelligent transport system supports urban smart mobility (Mangiaracina, 2017; Papa, Gargiulo & Russo, 2017; Battarra, Zucaro & Tremiterra, 2017). An intelligent transport system (ITS) means the advanced mode of transportation systems that include many pieces of software, which are helpful for safe transportation, diminish traffic congestion, reduce air pollution, increase energy efficiency and promote the development of the associated industries (Chandra, Harun & Reshma, 2017). According to Directive 2010/40/EU, intelligent transport systems "integrate telecommunications, electronics and information technologies with transport engineering to plan, design, operate, maintain and manage transport systems". Intelligent transport systems encompassing modern technological and organisational transport solutions enable, among other things, traffic control, the creation of special zones of limited access and low CO_2 emissions by limiting the number of private cars in city centres. ITSs aim to increase the safety of traffic participants and to improve the effectiveness of the transport system as well as to protect the natural environment. They undoubtedly comprise the most effective instruments for the improvement of city transport system's effectiveness and quality (Ministry of Transport…, 2013). In other words, ITSs are advanced applications which enable various users to be better informed and make safer, more coordinated, "smarter" use of transport networks (Directive 2010/40/EU).

2. Main concepts, challenges, and practical solutions of smart mobility

Smart mobility supposes developing logistic and transport activities using digital smart technologies, the mandatory existence of online databases, traffic optimisation and aims to reduce the negative effects of mobility (especially pollution) and optimise resource consumption. The transport system (public and private), as well as heavy goods transport, represent the support system for mobility services, which are vital for the city and citizens (Czech et al., 2018). Public transportation management must help the municipality to make the public transportation easier to use and more reliable, and at the same time help the operations optimisation with the new embedded digital features, such as issuing tickets and traffic lights synchronisation for traffic decongestion, increasing the efficiency, the safety and the coordination between different transport networks from the city. The benefits of such efficient management would be:

- real-time information about the public transportation,
- more efficient administration of the public transportation,
- possibility for citizens to access the information system online via smartphones,
- even greenlighting the traffic lights on request.

2.1. Challenges regarding smart mobility

The inefficient modes of transport, data centres and industrial activities represent important sources of air pollution. In this millennium, the transportation became the major source of carbon emissions worldwide. More than a quarter of these CO_2 emissions are due to transportation, and the road transport contributes around 65% of it (Turkensteen, 2017). Wrong political decisions which enable reducing taxes on importing second-hand cars contribute to increasing pollution levels. For example, such measure resulted in the increase of the number of second-hand registered vehicles in Romania amounting to over 71% in 2017 compared with the previous year. In 2016, the European Environment Agency identified transport as the single biggest GHG emitter (Lewald, 2017).

An intelligent transport system and traffic streamlining represent key factors to success in attracting business investors to a developing country. On the other side, the life quality of citizens, personal and business productivity can decrease as a consequence of traffic congestion. Furthermore, the rate of accidents and noise pollution increases, diminishing the air quality.

Accelerated industrial development has led to population growth in certain cities, the development of existing cities and the emergence of new ones, the creation of large industrial complexes that attract the workforce from villages or even from other cities. This growth determined the consumption of additional resources and generated more social problems (waste, pollution, health). Statistics indicate that more than 51 percent of the world's population from developing countries and 80 percent in those in the developed ones will live in cities in 2020 (Dirk & Keeling, 2009), and this number is forecasted to still rise in the coming years. Unfortunately, the increase of urban areas has not doubled by the development of the existing infrastructure, both of the transport and the urban utilities.

A very recent study developed by the World Resources Institute (WRI) and the World Bank suggested that governments should treat road accidents as a public health problem. Yearly, there are 1.25 million road accidents that lead to death due to the lack of road and pavement networks, inappropriate urban development, inadequate laws or their poor enforcement. Injuries and deaths caused by road accidents have a high economic impact. For example, the same report highlighted that 82 developing countries pay around $220 billion a year in the form of medical expenses and productivity losses. Consequently, there is more important to provide prevention actions by improving public transport systems, smart mobility solutions in and outside cities to reduce accidents and road deaths affecting developing countries (Welle et al., 2018).

2.2. Possible solutions

An example of implemented smart mobility is an urban traffic management system connected to a public transportation management system and an information management system about urban travels (including the priority for public transportation in crossroads). The system can be connected to an air quality monitoring system that allows the implementation of some regulatory measures targeting pollution during traffic jams (smart environment). Changing routes with heavy traffic and reducing pollution in inhabited areas increases the life quality of citizens and rehabilitates pedestrian routes in the urban transport network, making the city friendlier to its inhabitants (smart living).

The future ideas regarding a smart city aim first at making mobility smarter and cleaner (Lewald, 2017). One important measure to reduce air pollution is to reduce car traffic by mostly using public transport instead of private cars. An intelligent public transport infrastructure must target the reduction of traffic load. People must be (re-)educated with civic skills, and authorities must use gamification mechanisms which reward responsible behaviour and punish the wrong attitude. Awareness about environment changes can be boosted by incentives to change behaviours. The promotion must focus on the idea that efficient mobility does not require vehicle ownership. Car owners may also be discouraged by toll charges or congestion charges implemented in many cities. A strategic lever to control congestion might be the use of parking charges, congestion time pricing for downtown parking areas, park-and-ride location along the metro, tram or rail line, which could have a positive impact on the utilisation of the public transport. An interesting and functional example is Shanghai Uber for bike system (van Mead, 2017). Combining the use of metro with bike-sharing from home to office and back could be a solution for replacing the travel to work with own cars, also considering that cars remain parked 95% of the time (Florea & Berntzen, 2017).

Smart public transport uses the technology to provides public transport users with a better user experience. The use of sensors and the GPS (Global Positioning System) technology can provide real-time data on arrivals and departures of public transport. Smart ticketing solutions may use smart cards or mobile phones to make ticketing more efficient from a user's point of view (Florea & Berntzen, 2017). Online route planners which may provide much more useful information beside the travelled distance and crowded zones, such as air quality, road profile, profit might be obtained on each route, may help users choose the most efficient route from one location to another.

A city's intelligent traffic management must mitigate congestion and use all available information, even provided by citizen participation, as a foundation for planning a multimodal transport system including its predictive operational control. The data

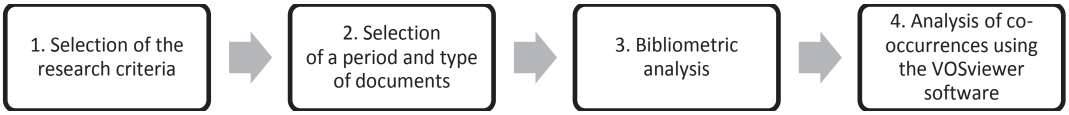

Fig. 1. Methodology of research

collected from smart public transport can be used for real-time situation reports and may also be used by public transport planners to adjust timetables, increase the number of buses at rush hours, change routes, create new routes, and adjust fares. Social media may be mined to find citizen perceptions regarding a public transport system. The important challenge is "how can we get more people to travel by public transport, in a region where most people prefer to travel by car?" (Johannessen & Berntzen, 2016). However, it must be kept at an equilibrium between business goals for improving the quality of life, maintaining the city's sustainability development, and the social participation and responsibility.

Since reducing the number of cars is very difficult to be accomplished, the effort for keeping a clean environment must be supported by industrial companies, especially automobile manufacturers, who need to develop low-emission mobility strategies (Lewald, 2017). The polluting emission minimisation policy should be implemented through the production of new vehicles and engines, including electric cars, and applied to existing cars. For example, Volvo will stop developing the new generation diesel engines and will focus on electric vehicles (Caughill, 2017). Other companies develop new particulate filters that are very effective in cutting emissions from existing diesel cars.

Typical IT solutions aiming to improve air quality and make mobility smarter and cleaner are:

- developing new heuristic algorithms to measure, evaluate and minimise CO2, NOx, and CO emissions in multi-depot Green Vehicle Routing problems (Turkensteen, 2017) with economic and social applicability;
- applying machine learning algorithms in solving Ridesharing problems to reduce vehicle emissions, maintaining too of decent living standards through development of infrastructure and qualitative services (Jalali et al., 2017);
- developing Breath Journey software applications that combine GPS track with air quality for travel planning which can show the distance information, data regarding the pollution levels on the respective routes. Thus, the programming paradigm will change from Software as a Service (SaaS) to Mobility as a Service (MaaS), providing very accurate, real-time, customised, wireless mobility information services regarding travel planning, journey time, air quality, online booking and payment facilities (Florea & Berntzen, 2017).

3. Research methodology

To achieve the aim of the article, the authors conducted a bibliometric analysis of scientific articles. Fig. 1 presents the methodology stages.

The methodology involved the following four stages:

1. Selection of the research criteria:
   - scientific articles listed in the Web of Science database referringto "urban smart mobility" or "urban intelligent transport system" in their topic;
   - scientific articles listed in the Scopus database referring to "urban smart mobility" or "urban intelligent transport system" in titles, keywords or abstracts.
2. Selection of a period and type of documents:
   - scientific articles published between 2000 and 2017.
3. Bibliometric analysis:
   - analysis of 610 articles published in the Web of Science database, and 524 papers listed in the Scopus database;
   - the analysis included: the number of publications in the analysed period, the citation analysis, research/subject area analysis of articles published in both databases and the most frequent keywords in articles listed in the Scopus database.
4. Co-occurrences analysis:
   - an analysis of the occurrence of key terms indicated by authors in the Scopus database and analysis of a map of current research trends, which shows the existing relationships between those keywords.

Within the last stage of the analysis, the authors prepared a map with the VOSviewer software (a tool for constructing and visualising bibliometric networks), which used advanced layout and clustering techniques to show the existing relationships between keywords characterising articles from the Scopus database. The program highlighted the frequency and co-occurrence of keywords that appeared in the network (Siderska & Jadaan, 2018). The program also combined the analysed set of data into clusters, using the state-of-the-art techniques for the network layout and providing network clustering (van Eck & Waltman, 2017; Glińska & Siemieniako, 2018). It has allowed identifying the main areas of research in urban smart mobility.

4. Research results

The concept of a smart city, especially smart mobility and intelligent transport systems have become very popular in recent years. To analyse the current research trends among publications dealing with urban smart mobility or an intelligent transport system (ITS), the authors started with verifying the number of publications available in the Web of Science and Scopus databases (Fig. 2). The authors carried out the analysis of the number of publications after the year 2000, when the number of publications exceeded seven in the Scopus and two in WoS databases.

The number of articles published in 2000–2017 that included references to the concept of urban smart mobility or ITS was 610 in the case of WoS database and 524 in the Scopus database. Analysing the number of works in each subsequent year, one can first notice a mild increase in the interest in this subject after 2006 and a significant one after 2014. It should be noted that the popularity of publications dealing with urban smart mobility indexed in both databases is currently characterised by an upward trend or journals probably did not finish the indexing process). Since 2015, the number of publications in the analysed context exceeded 100 works per year in the WoS database.

Fig. 3 presents the most popular research area of articles indexed in the Web of Science database (the size of the font used in the illustrations below reflects the number of papers from a particular area). The research areas which exceeded 200 papers referring to the analysed concept were "Computer Science" and "Engineering". The research area showing over one hundred articles was "Transportation". Other mainly represented areas were: "Telecommunications", "Urban Studies", "Environmental Sciences Ecology", "Science Technology Other Topics" and "Business Economics". In the Web of Science database, it was also possible to identify the most popular WoS categories of published articles. According to our analysis two main WoS categories, which include more than 100 articles, were: "Engineering Electrical Electronic" and "Transportation Science Technology".

In contrast, all the identified articles in the Scopus database mainly represented three subject areas: "Engineering" (290), "Social Sciences" (211) and "Computer Science" (210). The number of publications in the areas "Mathematics" and "Environmental Science" exceeded 50 papers (Fig. 4). It should be noted that WoS and Scopus databases differ in scope, data volume, coverage with unique sources and articles. Moreover, each database is characterised by different names of research/subject area. However, as part of this bibliometric analysis, both databases consider the engineering and computer science perspective in the research area involving urban smart mobility and also refer to business. Some of the analysed publications pertain to the research area "Business economics" in the Web of Science database and the subject area of "Business, Management and Accounting" in the Scopus database. The analysis of the research/subject areas of articles listed in both databases, lead to the observation of similar trends. These results are in line with our statements from the beginning of Section 1, where we have shown that Computer Science creates the tools considering the future plans for Transportation with large applicability for Business companies and Municipality, under the environmental regulations and for the well-being of citizens.

To take a closer perspective of the contemporary research trends dealing with urban smart mobility, the authors analysed five the most cited publications available through the Web of Science and Scopus databases (Tab. 1).

Papers have been thoroughly analysed by authors of this article, and they are mainly focused on current trends in smart cities and innovation of technology. Top three most cited articles are the same in both databases, but a higher number of citations refers to the Scopus database. Judging by a publication's title and sources but also analysing the abstract of these most cited papers, we appreciate that Tab. 1 is in line

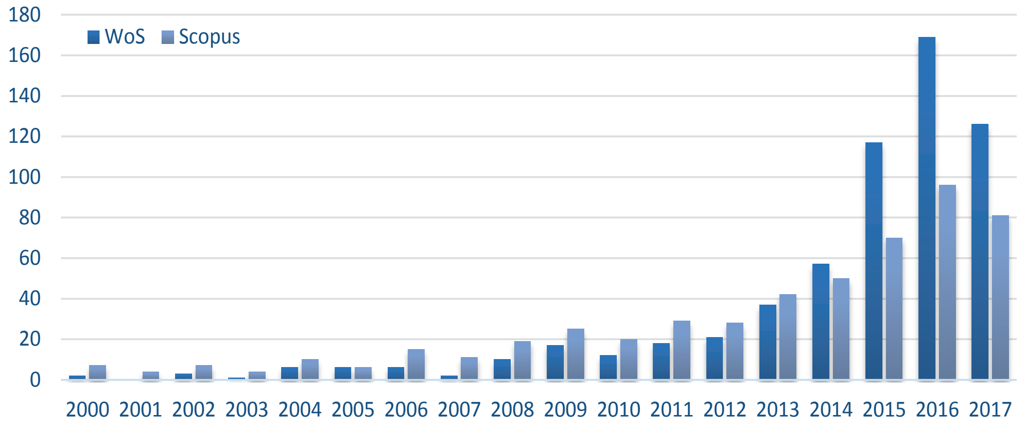

Fig. 2. Number of publications indexed in the Web of Science (WoS) and Scopus databases referring to the concept of urban smart mobility and ITS between 2000 and 2017

Fig. 3. The most popular research area of articles indexed in the WoS database referring to the concept of urban smart mobility between 2000 and 2017

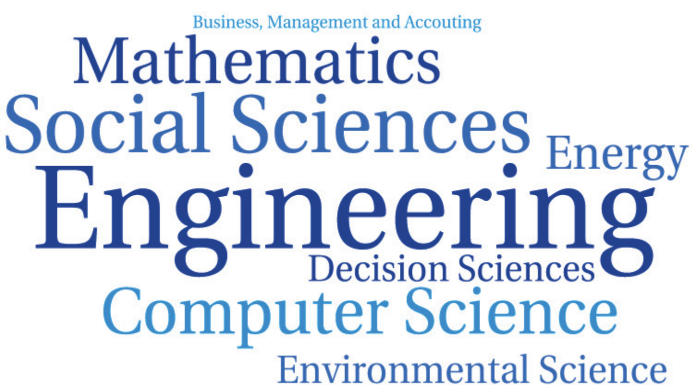

Fig. 4. The most popular subject area of articles indexed in the Scopus database referring to the concept of urban smart mobility between 2000 and 2017

Tab. 1. The most cited articles dealing with urban smart mobility or intelligent transport system in the Scopus database published between 2000 and 2017

Position in the ranking	Name of database	Author	Title of publication	Source	Year of publication	Times cited
1	Scopus & Web of Science	Quddus, M. A., Ochieng, W. Y., & Noland, R. B.	Current map-matching algorithms for transport applications: State of the art and future research directions	*Transportation Research Part C: Emerging Technologies*, *15*(5), 312-328	2007	398 (Scopus) 297 (WoS)
2	Scopus & Web of Science	Batty, M. et al.	Smart cities of the future	*European Physical Journal: Special Topics*, *214*(1), 481-518	2012	304 (Scopus) 241 (WoS)
3	Scopus & Web of Science	Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F.	Current trends in smart city initiatives: Some stylised facts	*Cities*, *38*, 25-36	2014	265 (Scopus) 209 (WoS)
4	Scopus	Lee, U. et al.	Mobeyes: Smart mobs for urban monitoring with a vehicular sensor network	*IEEE Wireless Communications*, *13*(5), 52-57	2006	207
4	Web of Science	Min, W., & Wynter, L.	Real-time road traffic prediction with spatio-temporal correlations	*Transportation Research Part C – Emerging Technologies*, *19*(4), 606-616	2011	157
5	Scopus	Pelletier, M. P., Trépanier, M., & Morency, C.	Smart card data use in public transit: A literature review	*Transportation Research Part C: Emerging Technologies*, *19*(4), 557-568	2011	201
5	Web of Science	Hidas, P.	Modelling lane changing and merging in microscopic traffic simulation	*Transportation Research Part C – Emerging Technologies*, *10*(5-6), 351-371	2002	145

with Fig. 3. The concept of smart mobility is a pillar of a smart city strong linked with transportation issues (routing, digitalisation services, road traffic prediction, etc.), municipality decisions and strategy, based on information and communication tools and technologies.

The literature review was preceded by a bibliometric analysis based on the Scopus database, which enabled the authors of the article to indicate the tendencies and trends in the field of urban smart mobility research. As a part of the analysis, the authors identified key terms appearing most often in articles dealing with urban smart mobility or urban intelligent transport system published in the Scopus database in the last 17 years. To present a clear visualisation, this paper focuses on those key terms which were recorded at least ten times within the group of publications being studied were considered (Fig. 5).

Within the conducted analysis, it was possible to notice three most frequent keywords, such as transportation, urban transport, and intelligent systems. Key terms which came up repeatedly included intelligent transport system, urban transportation, smart city, mobility, vehicles, electric vehicles, and intelligent vehicle highway system. There was a group of keywords connected to particular categories of advanced computer analysis, most of these applied in software applications developed for smart mobility: computer simulation, modelling, optimisation, algorithm, numerical model, forecasting, Ad Hoc Networks. It is also possible to see keywords closely linked to the implementation of ITS referring to traf-

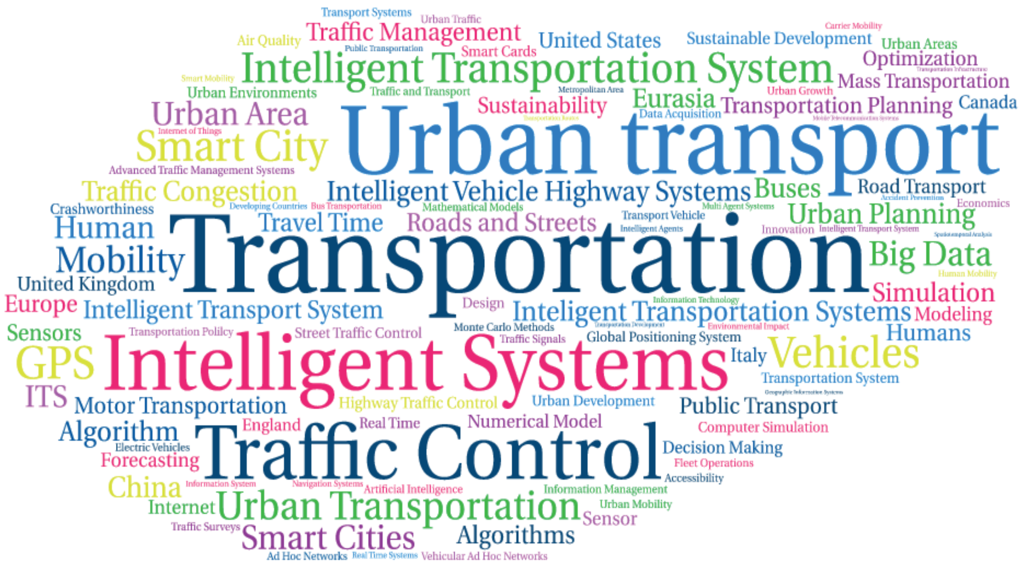

Fig. 5. Key terms which come up repeatedly in publications in Scopus database in years 2000-2017

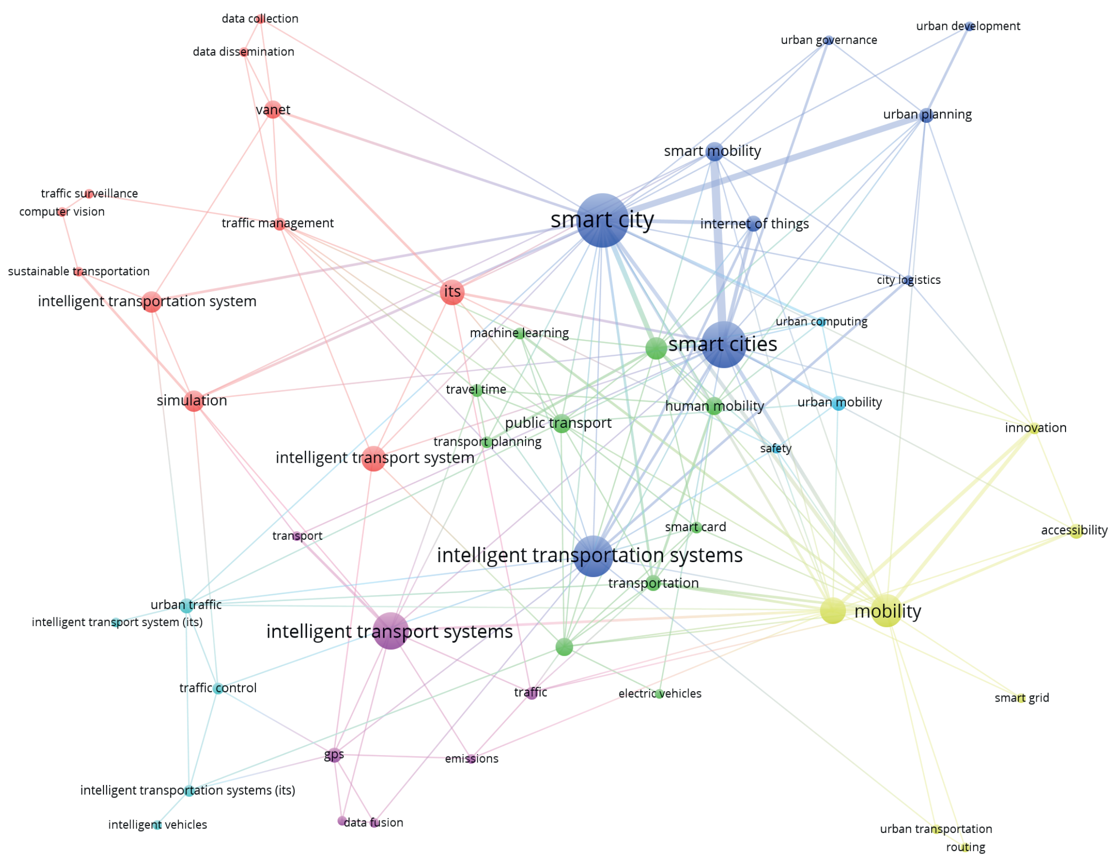

Fig. 6. Map of current research trends based on co-occurrence of the authors' keywords in publications referring to urban smart mobility or intelligent transport system from the Scopus database in the years 2000-2017

Source: authors own study using VOSviewer Software.

fic problems: traffic control, traffic congestion, travel time, roads and streets, urban traffic, traffic surveys, transportation planning, real-time, advanced traffic management systems, street traffic control. The next group was words related to elements of public transport: mass transportation, busses, and public transportation. A separate group of keywords were related to the environment such as air quality, sustainable development, and sustainability. Other smart city challenges related to city crowding were reflected by some keywords, such as urban growth, urban areas, urban mobility, and urban planning. It should be noted that there were also names of countries and regions, for example, Italy, United Kingdom, United States, Canada, China, Europe, and Eurasia.

In the next part of the study, the authors created a map displaying relations between the analysed keywords. The central part of the map shows key terms which appear the most frequently. Based on the data presented in the Fig. 6, some tendencies may be observed (the size of the point and font representing each term show the frequency with which this key word occurs). First, the resulting network is characterised by numerous connections and looks rather dense.

The VOSviewer software enabled authors to determine how often each item occurred within the network as well as how often the elements were cited together. The use of the program also facilitated the combining of the analysed set of data into clusters which were then marked out on the map in different colours. The program discerned 7 clusters of terms' co-occurrences which, all together, included 52 words. It must be said that being a member of a given cluster meant that the given phrases occurred together most often, but it does not preclude them from occurring with other terms. The main points referred to in most works included especially a smart city, smart mobility, intelligent transport system, sustainability, and mobility. The first cluster was located around the term a smart city, which co-occurs most frequently with such terms as smart mobility, urban planning and intelligent transport system. Concepts which had the strongest links to others within the network were the same as the terms listed above. The issues most strongly connected with others within the network (which appeared most often in the analysed set of publications and had the highest co-occurrence ratio), were: a smart city, intelligent transportation system, big data, sustainability, and public transport (Tab. 2). Authors of the article proposed the name of each cluster considering the majority of terms that each cluster contains.

The first resulting cluster "Computer simulation of urban traffic" is composed by a combination of important topics of Computer Science, namely Computer Vision, Simulation, Data Collection and Vehicular Ad Hoc Networks (VANET) with their applications in the transportation sector, traffic surveillance and traffic management. According to the literature, the research and development trends in computer simulation and urban traffic fields aim using and implementing machine learning algorithms for improving the accuracy of applications dedicated to lane keeping, prevention of collisions, self-driving cars, simulation of new routes or forecasting new traffic scenarios, etc (Mobileye, 2018). Machine learning algorithms, especially the artificial neural networks, represent one of the main trends in Computer Vision (constantly evolving), which helps in solving some of the hardest problems of the urban traffic. The reduction in traffic accidents is planned by using embedded systems based on Computer Vision which projects the existing image from the front of the truck on its back to help other traffic participants who want to overtake the truck (Samsung Electronics, 2015). There is an increasing opportunity in intelligent transport systems to adopt Computer Vision and video analysis for traffic measurement (Buch et al., 2011; Petrosino & Salvi, 2015). The next stream of research within the cluster 1 concerns the research on Vehicular Ad Hoc Networks (VANET), related to their security features, challenges, attacks (Mokhtar & Azab, 2015), and the challenge of routing (Li & Wang, 2007). Future research trends identified in the literature which are related to Computer simulation of urban traffic focus on the development of effective algorithms of managing urban traffic and simulate network-wide traffic efficiently (Nellore & Hancke, 2016).

In the second cluster "Urban public transport", the merging of Computer Science concepts with those specific to Urban Public Transport may be observed. Aiming for a more effective urban public transport, the public is engaged in city-related decision-making by using ubiquitous smart devices and applying the Gamification concept, also crowdsourcing and crowdsharing data to create the premises of big volumes of data. Machine-learning and smart cards are useful in adding intelligence to any devices, enhancing mobility, implementing smart parking systems, traffic lights controllers, etc. In the works by Dobre and Xhafa (2014), based on solutions designed

Tab. 2. Clusters identified through the analysis of co-occurrence of the authors' keywords

Items	Occurrences	Co-occurrence
Cluster 1 "Computer simulation of urban traffic"		
Computer vision	4	2
Data collection	4	3
Data dissemination	4	3
Intelligent transport system	14	6
Intelligent transportation system	11	5
ITS	14	9
Simulation	8	11
Sustainable transportation	4	3
Traffic management	6	9
Traffic surveillance	4	2
Vanet	9	6
Cluster 2 "Urban public transport"		
Big data	12	14
Electric vehicles	4	2
Human mobility	9	7
Machine learning	5	6
Public transport	10	13
Smart card	5	7
Transport planning	5	4
Transportation	8	9
Travel time	6	7
Urban transport	9	12
Cluster 3 "Urban smart transport planning"		
City logistics	4	6
Intelligent transportation system	26	15
Internet of things	8	6
Smart cities	31	21
Smart city	37	24
Smart mobility	10	9
Urban development	4	2
Urban governance	4	4
Urban planning	7	9
Cluster 4 "Innovations in urban transportation"		
Accessibility	7	4
Innovation	5	7
Mobility	20	20
Routing	4	2
Smart grid	4	2
Sustainability	15	14
Urban transportation	4	3
Cluster 5 "Data fusion in ITS"		
Data fusion	4	3
Emissions	4	4
GPS	7	8
Intelligent transport systems	23	10
Localization	4	3
Traffic	6	7
Transport	4	3
Cluster 6 "Intelligent solutions in urban traffic"		
Intelligent transport system (ITS)	4	1
Intelligent transportation system (ITS)	5	5
Intelligent vehicles	4	1
Traffic control	5	5
Urban traffic	7	9
Cluster 7 "Safety of urban computing"		
Safety	4	6
Urban computing	4	5
Urban mobility	7	5

Source: authors own study using VOSviewer Software.

to support the next-generation Big Data applications, cities are emphasised as areas with Big Data having a direct impact on the quality of life in a city. It should be pointed out that this data can be very useful to transit planners. According to Weziak-Białowolska research (2016), the dissatisfaction with public transport contributes significantly to the dissatisfaction with life in a city. Promoting the use of urban public transport helps in decreasing traffic congestion and air pollution in cities and improving human mobility, which is mostly related to management of passenger transport means (Yue, Chye & Hoy, 2017). Another important aspect of research in this field is smart card systems, which produce large quantities of very detailed data on onboard transactions and is often used by public transit agencies (Pelletier et al., 2011). In relation to urban public transport trends, we may state that the situation depends on the development degree of each country. The developing countries must improve their infrastructure and apply new features of public transport inside and outside the cities while the developed countries put their efforts in research studies to find new solutions that combat the city crowding or that reduce air and noise emissions, etc. Large cities often have a high demographic density and in consequence make a greater effort to develop their public transportation systems (Jun, Kwon & Jeong, 2013). The recent research trends identified in the literature and related to urban public transport, mainly focus on the possibility of prioritising public transport and reducing the time of travel (U.S. Department of Transportation, 2017; Jimenez, 2018).

The third cluster "Urban smart transport planning" is located in the map's centre and involves the general notion of a smart city. As already mentioned, smart mobility represents just a dimension of the smart city concept but one very important, strongly interrelated with other dimensions, such as the smart environment or smart living. The main task of a municipality (city) is to plan, govern and apply developmental solutions to make the public transportation easier to use and more reliable. The "Urban smart transport planning" is a wide area of research, in which researchers also analyse the problems particular to all other clusters. Despite the common goal, urban transportation planning has no universal solution (what works in one place does not work in another). The problem is critical in large cities with millions of inhabitants or in developing cities faced with an increasing rate of urbanisation. The planning initiatives involve the allocation of special lanes for the public transport and creation of incentives for electric mobility, all of these actions aimed at changing and extending the existing urban infrastructure. Many good measures in this field do not necessarily emerge from research but also from exchanges of good practice between cities that have implemented smart city features. Researchers define qualitative and quantitative indicators to measure the quality of planning solutions (emission estimations, travel time, customers served within a specified time frame, etc.). The importance in domains, such as urban planning, sustainable mobility, transportation engineering, and transport planning, has been identified by many researchers (Batty et al., 2012; Neirotti et al., 2014; Mangiaracina et al., 2017). The interest of researchers in planning and designing of urban transport systems will definitely show an upward trend in the coming years due to the increasing problem of congestion in cities.

The fourth cluster "Innovations in urban transportation" which has been widely studied in the last decade, mostly represents a further challenge regarding mobility, namely, to bring innovative solutions to urban transportation in a mobility world but keep the sustainability target. The technology innovation and intelligent (green) solutions for urban transport systems are of strategic importance for the EU, which allocates significant funds for research in this field (Halicka, 2016). Starting with 2012, the EU developed the European Innovation Partnership in Smart Cities and Communities aiming to connect all local initiatives (of the government, businesses and community-based organisations) from EU countries and provide exchanges and assistance tools regarding smart city solutions that meet specific local needs. Such initiatives aim integrating quality services with improved accessibility into the urban transport network, providing passengers with real-time multimodal information, enhanced comfort (Gaggi et al., 2013). The essential direction of future research trends should concentrate on improving the integration of new shared mobility services with traditional public transport services, autonomous vehicles, car park management and car sharing services, which have already reshaped our life and another various smart mobility services (Yue, Chye & Hoy, 2017; Fagnant & Kockelman, 2015; Jalali et al., 2017) and solving environmental problems caused mainly by traffic congestion (Florea & Berntzen, 2017).

The fifth cluster "Data fusion in ITS" is based on using and extracting data regarding transport, route difficulties and traffic, and developing smart applications to reduce air pollution, reduce car traffic, emphasising the Mobility as a Services (MaaS) concept, providing very accurate, real-time, customised, wireless mobility information services regarding travel planning, journey time, air quality, online booking and payment facilities. In the last few years, the Global Positioning System (GPS) has been a major positioning technology for providing location data for ITS applications. According to the literature review by Quddus et al. (2007), a map-matching algorithm (which integrated positioning data with spatial road network data) could be used as a key component that supports the navigation function of ITS to improve its performance. The fifth cluster "Data fusion in ITS" is developed relatively recently and might exponentially evolve due to the pervasive computing, crowdsourcing, and a large amount of data provided by almost any sources. Data obtained from interconnected cars will be used by analytical tools to predict vehicle malfunctions and help the user to make a brief diagnosis after they notice car problems, discovering the reason and indicating the nearest auto service. The Mobility as a Services (MaaS) is a recent research trend and innovative transport concept, which may have a significant impact on current transport practices (Jittrapirom et al., 2017). The MaaS becomes more powerful, benefiting from innovations and research in wireless mobility information services like 4G/5G networks (Goodall et al., 2017). This abundance of data and means of retrieval, leads to mandatory research of the 7th cluster identified by us, which pursues keeping privacy and security of user data.

The cluster 6 "Intelligent solutions in urban traffic" was located on the margins of the map because it concerned one of less frequently occurring keywords. The implementation of ITS solutions brings several benefits for all road users: pedestrians, cyclists, public transport, drivers and the environment. The future research related to intelligent solutions should focus on improving intelligent traffic lights, intelligent, autonomous vehicles (Fagnant & Kockelman, 2015) and improving traffic control. The positive effects of ITS potential, namely traffic management in real-time, providing reliable and real-time updated information to the users (including unexpected road events) are well studied and established in the literature (e.g. Kolosz & Grant-Muller, 2015; Grant-Muller & Usher, 2014).

The last and simultaneously the smallest cluster 7 "Safety of urban computing" consist of only three items but is very critical ("safety" into "smart mobility" inside and outside the city) according to recent statistics that correlate injuries and car accidents to the lack of infrastructure and poor roads. Some publications are aimed at identifying the benefits of Information and Computing Technologies (ICT) in a Smart City and of the Internet of Things, which are tremendous (Adel et al., 2014). For instance, the research of Bitam and Mellouk (2012) proposed a cloud computing model (called ITS-Cloud) applied to the Intelligent Transportation Systems, which improves transport outcomes such as road safety, transport productivity, travel reliability, informed travel choices, environment protection, and traffic resilience. The recent research trends related to the safety of urban computing mainly focus on improving data reporting systems, monitored using reliable data that can be publicly shared (e.g. Welle et al., 2018).

The main trends of research areas that appear in scientific articles published in years 2000–2017 dealing with urban smart mobility and intelligent transportation system are those which refer to the smart city, sustainability and public transport. The latest key terms characterising published articles besides phrases connected to the smart city and intelligent systems refers to, i.e. traffic control, vehicles, traffic congestion, big data, urban planning and mass transportation.

Conclusions

From the scientific point of view, those analyses lead to following conclusions:

- there is a systematic increase in the interest among academics in the analysed field of study between 2000 and 2017;
- the analysis allows indicating the urban smart mobility and intelligent transport system as rapidly developing fields of study, characterised by essential issues for future cities and the main contributions in the field comes from Computer Science and Transportation Science Technology researchers;
- in the last five years, there has been an enhancement in the production of scientific papers dedicated to smart mobility;
- the conclusions of this study can be used by municipalities, the business sector, and researchers to determine the trends in the smart mobility field and to choose proper decisions for improving the quality of life of citizens;
- a strong research trend consisted of the analyses referring to the smart city, intelligent transportation system, big data, sustainability and public transport;
- from the perspective of looking for future research gaps in the analysed context, infrastructure design and air quality protection, climate change, and city crowding were less frequent areas in the scientific literature. Regarding the future cities, the infrastructure is not taking into account "as much as it should", urban planning and the transport system is not designed considering the industrial developments and the prediction of the population that will live in cities. The air quality factor and the environment are only considered to a small extent although traffic problems have a direct impact on the environment, human health and, ultimately, the economy.

Also, the machine learning concept will be ubiquitous in future smart devices and applications implemented not only to mobility and transport systems;

- at the end of our analysis, we propose 7 clusters of term co-occurrences of most author keywords in publications referring to urban smart mobility or intelligent transport system.

Authors have chosen to analyse articles published in two most representative databases and conducted the co-occurrence analysis on articles listed in on Scopus database. As a further work, the scope of analysis should be expanded to include works indexed in other databases (for example SpringerLink, ScienceDirect, EBSCO etc.). The bibliometric analysis is still one of a few sources allowing for the wide perspective of the issues undertaken by scientists as well as familiarising with the development directions of a given issue.

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