THE ROLE OF ICT IN THE SMART CITY CONCEPT

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A b s t r a c t

The concept of a smart city enables the effective implementation of public services despite the negative consequences related to population growth in large cities. City authorities, in the face of growing demand for public services, often use a wide range of smart city instruments in various areas of operation. Despite the fact that a large part of innovative solutions is widespread and used, such as intelligent transportation systems or e-office, new opportunities are still emerging which are aimed at improving the quality of life for city dwellers.

The aim of the article is to define the role of ICT in smart city management. The subjects of analysis are innovative instruments used in technologically advanced cities as well as contemporary challenges facing city management.

The functioning of the city depends to a large extent on access to the communication network, mobile devices as well as on infrastructure connected with them. Therefore, it is necessary, on the one hand, to ensure the capacity of connections and network communication, and, on the other hand, to involve citizens in the process of creating new solutions.

ROLA ICT W KONCEPCJI *SMART CITY*

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A b s t r a k t

Koncepcja miasta inteligentnego umożliwia efektywną realizację usług publicznych, mimo występowania negatywnych konsekwencji związanych ze wzrostem populacji w dużych miastach. Władze miejskie w obliczu rosnącego popytu na usługi publiczne często korzystają z szerokiego instrumentarium *smart city* w różnych obszarach funkcjonowania. Mimo że duża część innowacyjnych rozwiązań jest rozpowszechniona i wykorzystywana, np. inteligentne systemy transportowe czy e-urząd, to wciąż pojawiają się nowe możliwości ukierunkowane na podnoszenie jakości życia mieszkańców miast.

Celem artykułu jest określenie roli ICT w zarządzaniu *smart city*. Przedmiotem analizy są nowatorskie instrumenty stosowane w zaawansowanych technologicznie miastach, a także współczesne wyzwania stojące wobec zarządzania miastem.

Funkcjonowanie miasta zależy w dużej mierze od dostępu do sieci komunikacyjnych, mobilnych urządzeń oraz sprzężonej z nimi infrastruktury. Dlatego też konieczne jest z jednej strony zapewnienie przepustowości połączeń i komunikacji sieciowej, a z drugiej zaangażowanie mieszkańców w proces powstawania nowych rozwiązań.

Introduction

According to the International Organization for Migration, every week about three million people move to cities around the world. Considering global trends, it is estimated that by 2050, the population of cities will have increased to 6.4 billion people (*World Migration Report*, 2015, p. 1). This causes a number of consequences for the functioning of cities, such as, for instance: an increase in the degree of congestion, waste production, water and energy use, and CO_2 emissions. Therefore, city authorities are faced with many challenges in the field of energy management, waste management, public space, transportation management, and administration. The consequence of this is the need to constantly monitor the level of city development and implement innovative solutions in the above-mentioned areas. It should be noted that city management is also subject to high pressure and encounters numerous restrictions. It is connected with the constantly growing expectations of citizens in terms of quality of life, more restrictive environmental protection laws as well as with depleted tax revenues.

It is worth to mention that the increase in the number of inhabitants mainly concerns large cities and metropolises. The problems of smaller cities sometimes have a completely different character and are related to, among others, depopulation. Despite this, there are a number of similar challenges in all cities related to air pollution, safety or transport.

The concept which can support city authorities in dealing with current and future challenges is smart city. In the literature one can come across numerous definitions of this concept, which, however, are very general and thus make it difficult to state clearly when a given city can be considered to be a smart one. It is even more difficult to identify specific development paths for cities. It is connected with the specificity of a given place, the cultural characteristics

of citizens, the level of social trust, the attitude to building relations, etc. Therefore, there are many possibilities and instruments which can support the authorities in overcoming development barriers. A very wide catalog of instruments is based on the use of information and communication technologies (ICT) that allow the processing of urban data and improving the quality of life of society.

The objective of the article is to present contemporary tendencies in building a smart city based on ICT as well as to present significant challenges facing city management. The study attempts to define the concept of a smart city, and to present ICT-based instruments applied in various cities all over the world. The study presents a definition of the smart city concept, as well as instruments from various ICT-based cities around the world. Moreover, major development challenges have been identified that should be taken into account by city authorities when conducting their activities.

The article is a combination of theory and practice. Literature studies and examples from the last few years have been applied.

The structure of the study is as follows. After the introduction, section I contains the definitions of the smart city concept and the role of ICT. Section II focuses on identifying the basic challenges of the smart city concept. The next part of the article contains a set of exemplary instruments of the discussed concept, which use ICT. The last part of the article is a summary which contains the most important conclusions derived from the analysis carried out.

The Smart City Concept. A leading role of technology

In the last few decades, many expressions of modern cities have been created to meet the demographic, climactic and economic challenges of the 21st century. In the subject literature, you can find certain terms that are frequently applied with reference to a city of the future. These terms include 'information', 'digital', 'green', 'slow', 'clever', 'knowledge', 'intelligent' 'creative' or 'smart'. However, the most popular one is the term – 'the smart city', which also refers to the developmental concept of the city. There is no commonly accepted definition of what 'smart city' is. In a large part, emphasis is laid on the use of information and communication technologies (Farelnik & Stanowicka, 2016, p. 362). A smart city strives to solve development problems (also related to the availability of public services, transportation, and environment) through ICT, which are included in the urban infrastructure (Lee *et al.*, 2014, p. 82). They allow obtaining a vast amount of information from various areas of the city's functioning, processing them and making them publicly available. Municipalities, citizens and businesses benefit from this through an appropriate use of this information provided by sensors, meters, cameras, smartphones, and mobile devices. It is worth noting, however, that a smart city is not based only on technologies. Technology is a means

to achieve social, environmental, economic and cultural development (Nam & Pardo, 2014, p. 2). The important role of social inclusion cannot be underestimated, since it increases the quality of public decisions taken. Therefore, combining the quoted threads, a city can be considered smart if investments in human and social capital as well as in traditional (transport) and modern (ICT-based) communication infrastructure fuel sustainable economic development, and a high quality of life; all while being accompanied by effective management of natural resources and active participation among citizens (Caragliu *et al.*, 2011, p. 70).

Part of the definition of a smart city describes the city as a set of systems or areas of diverse character. For example, Weisi and Ping (2014, p. 69) distinguish six smart systems: social networks (health, education, security), regulations for business (administrative support, laws), transport (road networks, air and sea transportation), communication (broadband networks, wireless networks), water (water supply, water quality), and energy (utilization of rubbish, energy production). One can also analyse a city by taking into account a few more complex areas (Giffinger *et al.*, 2007, p. 12):

– smart economy – competitiveness – entrepreneurship, productivity, innovation;

– smart people – human and social capital – qualifications, creativity, lifelong learning;

– smart governance – social participation – public services, transparency of management, participation in making public decisions;

– smart mobility – transportation and ICT – local availability, ICT infrastructure, safe, innovative and ecological transport systems;

– smart environment – natural resources – pollution, environmental protection, management of natural resources;

– smart living – quality of life, living conditions, security, social cohesion.

In this article, selected ICT instruments from the area of intelligent environment and life, as well as, participation in decision making (intelligent management) were analyzed.

The smart city concept is not always perceived as a certain state or end result. One can come across the view that it is a process, an interaction between urbanization and ubiquitous digital technology (Hanna, 2016, p. 92, 93). This technology integrates physical infrastructure, local public institutions, the urban community and the geographic environment. It also increases the availability of data on the functioning of the city, which can be used to improve the quality of existing public services and create new ones, and to spatial planning. It also allows citizens to participate in the process of making public decisions. This integration consists in using, by inhabitants, various technological solutions supporting, among others: transport (intelligent transport systems), and the development of public spaces (applications enabling voting on infrastructure projects, reporting acts of devastation).

Despite the fact that the concept of a smart city is already relatively well recognized, there are still many uncertainties in the organization of strategic planning in this area. It results, among others from the fact that stakeholders (local authorities, research institutions, technology suppliers, developers, and non-profit institutions) frequently have conflicting interests. Moreover, the belief that the transformation itself in terms of gaining advanced technological infrastructure will bring many benefits is wrong (Angelidou, 2014, p. 3). In addition to infrastructure-related activities, in cities aspiring to be smart it seems necessary to have technological education programmes for residents, to promote participation in public decision-making and to create social innovations. There are many cases that show the lack of an appropriate approach to the implementation of the smart city concept. One of the major problems in this respect is the lack of involvement of residents in the process of planning specific solutions (Glasmeier & Christopherson, 2015, p. 8, 9). Innovation users should participate in the development of the idea and implementation of technology that is to serve them. At the same time, they support programmers with their experience and help adapt the product or service to specific needs. The lack of such interference may lead to situations where a technology is mismatched to reality.

Contemporary challenges for city management

Contemporary cities are becoming the arena of changes taking place globally in the economic and social spheres, related to the growing importance of information and communication technologies. The business sphere is undergoing a process of transformation towards a digital economy based on the use of the Internet and computer software. In consequence, a number of emerging economic trends can be observed. First of all, there is an intensification of co-operation between enterprises. The Internet is a tool by means of which it is easier to find business partners, conduct negotiations, or purchase materials and components. As a result, transaction costs related to, among others, communication, invoicing or payments are decreasing. Secondly, computer programmes support decision-making related to management, which facilitates an optimal use of resources. Thirdly, the Internet offers many opportunities to conduct marketing and sales activities, as well as to build a positive image. This is very beneficial from the point of view of consumers who exchange opinions about products on various types of internet forums and thus monitor the seller's quality and reputation. Fourthly, in the digital economy there is a change taking place in the customers' approach to the issue of owning the product. Nowadays, owning a product is not a necessity conditioning its use. Access is more important. A cultural product, (i.e. movies, music, books available in the form of streaming services) serves as an example.

The above changes in business activity occur simultaneously with the progressive digitization of social life. One can observe the great popularity of mobile devices with access to digital platforms and social networks. An increasing part of society uses ICT by using a range of services related to leisure time, health, education, culture, tourism and business. Moreover, there are technologies revolutionizing many aspects of everyday life. One of them is the Internet of Things (IoT). It is a new communication paradigm that provides access to, control of and interaction between various devices, such as, for example, household appliances, monitoring cameras, sensors, displays, and actuators (Zanella *et al.*, 2014, p. 22). This model facilitates the development of a number of applications that use a huge amount and variety of data generated by these devices. It can be used to provide new services to citizens, businesses and public administration. It is estimated that by 2020, 25 billion devices will have been connected to the network within IoT (Kazmi *et al.*, 2017, p. 21). IoT is perceived as a technology that allows effective resource management in many sectors. Therefore, it is widely used in city management in such areas as waste management (sensors in garbage containers, fleet management), energy management (lighting controllers, smart metering), security management (monitoring, notification systems), transport management (traffic and parking places control systems), etc.

New technologies used in city management gain enormous amounts of data. Contemporary urban development is created by new technologies that acquire enormous amounts of data. They are stored and analysed using cloud computing or big data instruments. At the same time, there is an increase in the number of network users and in the range of available internet services. All this makes that a key challenge for city authorities is ensuring an efficient transmission infrastructure, such as, for example, the Fifth Generation Mobile Communication System (5G).

The 5G network, which will be launched in Europe in the upcoming years, will allow the implementation of various services within the smart city concept – in the broader context, within the Internet of Things. It offers a number of benefits that the existing network technologies cannot provide. These benefits are as follows (*Smart Solutions for Sustainable Cities*, 2017, p. 7):

– high transmission speed – up to 20 Gbit/s enabling ultrafast mobile broadband internet;

– low latencies – less than 1 millisecond, which means that signals are transmitted almost in real time. This is a key utility from the point of view of managing the power transmission infrastructure, where in the case of voltage changes a quick response is needed to avoid failure. In addition, it will enable fast communication between autonomous cars (car-to-car) and other devices in the car (car-to-everything);

– the possibility of connecting 1 million devices to the network per square kilometre at the same time with guaranteed quality of services. This is a great

convenience for the operation of readers and sensors acquiring data on atmospheric conditions, the level of air pollution or congestion of streets.

The main challenge for the city authorities in the area of building the 5G network is cooperation with other public institutions (central level) and private enterprises involved in this process (e.g. providing access to municipal infrastructure during construction work).

In the digital world, however, one cannot forget about the most important link – people. In the smart city concept, particular emphasis should be laid on the processes of involving citizens in technological issues. The available tools should be popularised, and features and benefits explained. This is particularly important in the context of ageing societies and their limited use of devices and applications. The constant updating of knowledge and skills of citizens should be supported by city authorities in consultation with business communities. An example of such activity is a Danish city – the City of Aarhus (Snow *et al.*, 2016, p. 95). Since 2014, 'Internet Week Denmark' has been organized there, consisting of over one hundred events – meetings, lectures, workshops, and debates in which representatives of city authorities, mobile application developers, entrepreneurs, citizens, and non-governmental organizations take part. During the festival, new devices are presented, including training sessions in operating them. In addition, discussions are held in the form of a brainstorming session about the quality of life in the city. These discussions lead to formulating proposals for solutions the work on which is continued by the city authorities in cooperation with representatives of entrepreneurs. An interesting event under the 'Internet Week Denmark' is also the so-called 'Hackathons'. These are multi-day workshops in which teams of programmers, entrepreneurs, city officials, residents and other interested parties participate to solve specific problems or urban challenges. The effects of these works are usually applications that reduce the problem identified during the meetings. Hackathons are a way to create a lasting public-private partnership that affects the economic, social and environmental spheres of the city (Perng *et al.*, 2017, p. 3). A wide range of stakeholders who are involved in the restructuring of the city foster a better understanding of problems and create a bigger number of initiatives. Hackathons give the opportunity to integrate local society and build trust in public institutions. They bring concrete results that are often missing during meetings on programme documents or modernization plans. An example of such a result is an application developed in the American city of San Diego, which collects data on places where people gather and this sort of information could be found very useful, for instance, by owners of food trucks (Kosowatz, 2017, p. 35).

The involvement of citizens in the process of building a smart city is not only an expression of the maturity of civil society but also of a demand-based approach to innovation. It consists in engaging users' knowledge to create new products, services or concepts (*Popytowe podejście do tworzenia...*, 2012, p. 28, 29). Two elements are crucial in this approach. First, there needs to be an understanding

of the real needs of users to identify new opportunities to create innovation. Secondly, the innovation process is undertaken with the systematic involvement of users who are directly involved in the work of the product development team. Social inclusion is an expression of new trends in the approach to innovation management. Therefore, the residents together with the authorities design new solutions and participate in their creation and testing. In this way, users of these solutions take part in the innovation management process (planning, creating, testing). The existing model of interaction between the public and academic spheres and industry, the so-called 'triple helix', has been supplemented with users of innovation actively participating in creating new values. In this way, a quadruple helix model was created (Arnkil *et al.*, 2010, p. 65). The cooperation of the four areas mentioned above may be utilised for the sake of the development of various types of innovations, such as, for example, technological, social, product and service innovations. Therefore, it can be concluded that the demand-driven approach to innovation reflects the need for social inclusion, and the increased participation of citizens in identifying challenges and developing remedies.

Examples of ICT-based smart city instruments

The growing expectations of urban residents regarding the quality of public space and services as well as the quality of life have caused an increasing demand for new products and services.

Many companies have specialized in providing such instruments as, for example, traffic control systems, smart metering, urban lighting control centres, electric car rental, pneumatic waste disposal systems, renewable energy infrastructure, or hotspots. This interest in cooperation with local authorities is still growing because it is estimated that as early as by 2020 the global market for smart city solutions will be worth over 400 billion USD (Lea, 2017, p. 13). The most absorptive market is being created within public management, education, health and energy.

This article focuses on several ICT solutions which are oriented to the quality of life of residents and the natural environment.

Municipal services are obliged to constantly monitor security. One of the biggest threats, especially in American cities, is street shootings. High noise levels and vibrations often make it impossible to clearly identify a given noise such as a shot from a firearm and, consequently, call the police. Hence, already in 90 cities around the world, including Chicago, New York, Boston, and San Francisco, special sensors are used that capture the sound of a shot and immediately notify the police (TechRepublic, 2018). This technology allows the location to be identified precisely within several meters, records the number of shots and may identify the shooter. Work is underway to integrate sensors

with street lamps and to adapt them to receive such signals as the sound of broken glass, car collisions or spray painting. This should improve the efficiency of police intervention as well as the level of security of residents. The monitoring system is a widespread solution to ensure the safety of residents. In German cities, monitoring systems fulfill many different functions: such as detecting the intrusion of persons or vehicles into critical areas, unwanted objects in closed rooms, detecting and filing faces in a video stream, recognizing license plates on vehicles and matching them with blacklists, and analyzing queues in order to detect overcrowding (Telekom, 2018).

Another example of a new smart city instrument is related to the community action of citizens. The Smart Citizen project being implemented in Barcelona is focused on monitoring the level of pollution (Smartcitizen, 2018). Barcelona citizens use a special device to measure the composition of air, temperature, humidity, light intensity and noise level. The device contains sensors and a geolocation transmitter and can be mounted on a window sill or on a balcony. Using a Wi-Fi network, it systematically sends data to the main computer, which places it on the map. In this way, as a result of the collective action of citizens, a publicly available information platform about environmental conditions in individual districts of the city is being created. It enables citizens to make a comparison of conditions for living and running a business, make decisions about possibly moving out or finding a suitable place to have a bicycle trip.

Problems with finding a parking lot in the city are a natural consequence of population growth and increases in the number of cars. It is estimated that up to 30% of street traffic in city centres is caused by drivers looking for a place to park. It has been calculated that, for example, in Paris, each driver loses an average of about four years during his/her life on searching for a parking lot (Labcities, 2018). In San Carlos, the United States, parking lots are equipped with sensors that send a signal telling drivers whether there is any parking available or not. Drivers through an application on their phone can find and choose in this way a parking lot and pay the fee. Sensors have a number of advantages. They are durable and consume extremely little energy. One battery, for example, can last up to eight years. The street lamps in Bonn are dimmable, darken using motion detectors, and automatically turn on and off. In addition, public utilities proactively receive a message when a bulb is damaged or needs to be replaced. The networked street lamps will save up to 60 percent of operating costs (T-systems, 2018).

One of the exemplary new solutions in the field of city management is the system of route optimization for the municipal fleet, including dustcarts (Bioenabletech, 2018). It facilitates the planning of routes for municipal vehicles in a completely automated way. In the case of cities with a fleet of several dozen or several hundred vehicles, designating service areas creates many difficulties. The computer designating the route is connected with sensors reading the filling level of garbage containers, weather conditions, and the level of street

congestion. In addition, it takes into account the work schedule of people responsible for garbage collection. The system gives savings resulting from lower fuel consumption, reduced workload, and lower equipment usage. It also positively affects the reduction of CO_2 emissions.

An innovative project focused on saving water was implemented in Lyon, France (Robert *et al.*, 2017, p. 11, 12). A street was built there, under the surface of which there is a rainwater tank with a volume of 1,200 cubic meters. Rainwater from the tank is used by street sweepers and in this way the system contributes to keeping the streets clean. In addition, air temperature, soil moisture and tree growth sensors were installed in the nearby city park, which are connected to remotely controlled irrigation pumps supplied by water from the tank below the street. The monitoring of the irrigation needs of plants and the water level in the tank is done automatically via a computer.

The communication between city authorities and citizens is important in implementing the smart city concept. One of the possibilities in this area is a city portal providing information about public services (*Smart Solutions for Sustainable Cities*, 2017, p. 18). It allows a comparison of the effectiveness reached by individual departments of the city and promotes the transparency of activities. This solution has already been introduced in Liverpool, Boston and Los Angeles, where the networks publish information on:
– the number of city bus runs;
– the number of police officers on duty;
– average waiting time for help from municipal services;
– the percentage of graffiti removed from the walls in the last 48 hours;
– the number of street lamp failures removed in the last 12 months.

It is worth noting that smart city instruments do not always need to rely on ICT solutions. All activities aimed at improving the quality of life of citizens, the condition of the natural environment or management effectiveness are desirable. The introduction of a ban on entering the city centre for trucks or cars with low emissions standards or the implementation of one ticket for various types of city transport systems illustrate the point.

Summary

The smart city concept is nowadays a very popular way to counteract the effects of the growing urban population. There are different approaches to its implementation, but most frequently they are related to the wide use of network technology, mobile devices, sensors, cameras, etc. The common denominator for most of these solutions is their availability and the bandwidth of internet connections, which determines the offering of new services and the efficiency improvement of the existing ones. It is difficult to imagine that connections within

the security system or communication between autonomous cars are delayed or impossible due to network congestion. Therefore, a major challenge for smart city authorities is to ensure an adequate transmission infrastructure, such as, for instance, a 5G network. These activities should be performed simultaneously with the promotion of the idea of being smart among citizens. It is also necessary to include citizens in the process of developing new technological solutions within the framework of the model of a demand-based approach to innovation.

Implementation of new ICT solutions in cities is very expensive. Therefore, cities with limited investment opportunities may have problems financing them. It is worth mentioning that new technologies are not always an effective instrument for improving public services or the quality of life of residents. Such a situation may occur when there is no social acceptance of new solutions or the level of complexity of their application, for example: cities with an aging society, where most residents prefer more traditional payment for a public transport ticket or a car park than through a special application. It is important that the municipal authorities improve the effectiveness of their activities together with the inhabitants. A good practice in this area is the broad social participation in city management. In summary, real smart cities primarily use their human capital and then advanced technologies.

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References

Angelidou, M. (2014). Smart city policies: A spatial approach. *Cities*, *41*, 3-11. https://doi.org/10.1016/j.cities.2014.06.007.

Arnkil, R., Järvensivu, A., Koski, P., & Piirainen, T. (2010). *Exploring Quadruple Helix. Outlining User-Oriented Innovation Models*. Working Papers, 85, Tampere: University of Tampere.

Bioenabletech. Retrieved from https://www.bioenabletech.com/integrated-solid-waste-management-solution (25.01.2018).

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart Cities in Europe. *Journal of Urban Technology*, *18*(2), 65-82. https://doi.org/10.1080/10630732.2011.601117.

Farelnik, E., & Stanowicka, A. (2016). Smart city, slow city and smart slow city as development models of modern cities. *Olsztyn Economic Journal*, *11*(4), 359-370.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., & Meijers, E. (2007). *Smart Cities — Ranking of European Medium-Sized Cities (Report)*. Vienna: Vienna University of Technology, Centre of Regional Science.

Glasmeier, A., & Christopherson, S. (2015). Thinking about smart cities. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 3-12. https://doi.org/10.1093/cjres/rsu034 (22.01.2018).

Hanna, N. (2016). *Mastering Digital Transformation: Towards a Smarter Society, Economy, City and Nation (Innovation, Technology, and Education for Growth)*. Bingley: Emerald Group Publishing Limited.

Kazmi, A., Jan, Z., Zappa, A., & Serrano, M. (2017). *Overcoming the Heterogeneity in the Internet of Things for Smart Cities*. In I. Podnar Žarko, A. Broering, S. Soursos & M. Serrano (Eds.). *Interoperability and Open-Source Solutions for the Internet of Things*. InterOSS-IoT 2016:

Interoperability and Open-Source Solutions for the Internet of Things. Stuttgart. https://doi.org/10.1007/978-3-319-56877-5_2.

Kosowatz, J. (2017). Building a Smart City. *Mechanical Engineering*, *139*(08), 32-37. https://doi.org/10.1115/1.2017-Aug-1.

Labcities. Retrieved from http://www.labcities.com/16-tech-jobs-that-will-be-needed-for-the-future-of-smart-cities/ (18.01.2018).

Lea, R. (2017). *Smart Cities: An Overview of the Technology Trends Driving Smart Cities*. Advancing Technology for Humanities. Retrieved from https://www.ieee.org/publications_standards/publications/periodicals/ieee-smart-cities-trend-paper-2017.pdf (25.01.2018).

Lee, J.H., Hancock, M.G., & Hu, M-C. (2014). Towards an Effective Framework for Building Smart Cities: Lessons from Seoul and San Francisco. *Technological Forecasting & Social Change*, *89*, 80-99. https://doi.org/10.1016/j.techfore.2013.08.033.

Nam, T., & Pardo, T.A. (2014). The Changing Face of a City Government: A Case Study of Philly311. *Government Information Quarterly*, *31*, 1-9. https://doi.org/10.1016/j.giq.2014.01.002.

Perng, S-Y., Kitchin, R., & Donncha, D.M. (2017). Hackathons, Entrepreneurship and the Passionate Making of Smart Cities. *Open Science Framework*, *3*, Retrieved from https://osf.io/nu3ec/ (12.01.2018).

Popytowe podejście do tworzenia innowacji. Doświadczenia krajów skandynawskich. (2012). Warszawa: Polska Agencja Rozwoju Przedsiębiorczości.

Robert, J., Kubler, S., Kolbe, N., Cerioni, A., Gastaud, E., & Främling, K. (2017). Open IoT Ecosystem for Enhanced Interoperability in Smart Cities – Example of Métropole De Lyon. *Sensors*, *17*(2849). Retrieved from http://www.mdpi.com/1424-8220/17/12/2849/pdf (23.01.2018).

Smart Solutions for Sustainable Cities. (2017). Deutsche Telekom AG. Retrieved from www.telekom.com/resource/blob/508354/34b13446226d1164c5dcc0d0e7fb0eea/dl-171113-whitepaper-smart-city-en-data.pdf (15.01.2018).

SmartCitizen. (2018). Retrieved from https://smartcitizen.me/about (24.01.2018).

Snow, C.C., Håkonsson, D.D., & Obel, B. (2016). A Smart City is a Collaborative Community: Lessons from Smart Aarhus. *California Management Review*, *59*(1), 92-108. https://doi.org/10.1177/0008125616683954.

TechRepublic. (2018). Retrieved from www.techrepublic.com/ (17.02.2018).

Telekom. (2018). Retrieved from https://www.b2b-europe.telekom.com/download/smart-public-safety (17.12.2018).

T-systems. (2018). Retrieved from https://www.t-systems.com/blob/782570/b6c115fadd7e5c3ba7520cbb20fdf82e/DL_Best-Practice _FT03-Vernetzte-Stadt.pdf (15.12.2018).

Weisi, F., & Ping, P. (2014). A Discussion on Smart City Management Based on Meta-Synthesis Method. *Management Science and Engineering*, *8*(1), 68-72.

World Migration Report 2015. (2015). Geneva: International Organization for Migration.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for Smart Cities. *IEEE Internet of Things Journal*, *1*(1). https://doi.org/ 10.1109/JIOT.2014.2306328 (24.01.2018).