

SMART CITY IN THE ERA OF THE FOURTH INDUSTRIAL REVOLUTION

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Purpose: More than half of the world's population lives in urban areas. These areas cover only 2% of the earth's surface. 65% of global GDP is produced here, and more than 75% of global greenhouse gases are emitted from this area. This causes huge management problems and requires a transformation of urban life. The reconstruction of a city's functioning methods requires innovative solutions based on digital technologies and cooperation between all stakeholder groups. This article attempts to indicate the relationship and interaction between new urbanisation and the smart city concept and Industry 4.0 technologies.

Design/methodology/approach: The article is theoretical and is based on a review of literature and examples in the implementation of 4.0 technology in a smart city.

Findings: Interactions and integration of urbanisation processes and development of new technologies contribute to the change of the new smart city infrastructure. Modern information technologies help improve a city's functioning, not only for the better use of resources and improving transport systems, but also to improve energy efficiency and sustainable urban development. On the other hand, a smart city, accumulating social capital and attracting financial resources, has become the preferred place for the location of business. Therefore, this concept supports the new industrialisation.

Originality/value: The survey provided an answer to the question related to the scope of use of Industry 4.0 by a smart city. It was pointed out that these tools are of key importance for urban development. They give city managers tips on strategic directions of development, suggesting that Industry 4.0 instruments should be prioritised.

Keywords: living lab, smart city, Industry 4.0, new urbanisation.

Category of the paper: Research paper.

1. Introduction

Urban population growth, migrations and climate change are just a few reasons for smart city development. Currently, cities are looking for new solutions to their problems. These are increasingly based on new information technologies. I am aware that their use is not enough for a city to become smart, but ICT solutions, Internet of Things, Big Data, cloud computing or

Industry 4.0 is becoming a reality. At every step, we meet sensors that change the way we move in an urban space, increase safety and allow the collection of large data sets. Their analysis allows for drawing conclusions and better management of a city's resources. Access to large data sets allows one to build completely new markets and better tailor an offer to the needs of various stakeholder groups. Moreover, it is able to communicate with its own infrastructure, monitor the movement of its citizens and respond to them, resulting in the optimisation of the conditions prevailing in a city. All these will achieve the status of an intelligent city. Taking this into account for the purpose of this article, I would like to present the concept of a smart city from the perspective of the fourth industrial revolution, as well as to show how Industry 4.0 technology can contribute to improving the functioning of a city.

2. Literature Review – smart city in the context of the fourth industrial revolution

Although the concept of a "smart city" is becoming more and more popular, a generally accepted definition has not yet developed. Analysis of literature in this area allows one to distinguish two descriptions: (1) city based on ICT (m.in. Hollands, 2008; Komninos, 2008); and (2) a new paradigm in a city's development, where a key role is played by human and social capital, education and the environment (Neirotti, De Marco, Cagliano, Mangano, Scorrano, 2014; Giffinger, Fertner, Kramar, Kalasek, Pichler-Milanović, Meijers, 2007; Lombardi, Giordano, Farouh, Yousef, 2012; Caragliu, Del Bo, Nijkamp, 2009). The technological smart city trend is reflected, among others, in the definition of T. Bakici, E. Almirall and J. Wareham, (2013), according to which: "smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality". Similarly, IBM defines a smart city as: "A city is an interconnected system of systems. A dynamic work in progress, with progress as its watchword. A tripod [infrastructure, operations, people] that relies on strong support for and among each of its pillars, to become a smarter city for all" (IBM, 2015). This definition includes three key features of a smart city: (1) instrumented, i.e. the presence of ICT solutions in a city (sensors, mobile devices); (2) connected, i.e. the availability of connections between the real and virtual world using instrumentation; and (3) intelligent, meaning the ability to use new technologies in a city's development process (Harrison, Eckman, Hamilton, Hartswick, Kalagnanam, Paraszcak and Williams, 2010).

Proponents of this approach say that cities will be on the verge of a revolutionary breakthrough and will become cities of dreams. Each sphere of life will be digitised, and applications, algorithms and artificial intelligence will reduce congestion, prevent crime and create free public services (Giffinger, Fertner, Kramar, Kalasek, Pichler-Milanovic,

Meijers, 2012, p. 2291). But will it really be like this? Is the reconfiguration of a city into technological problems enough to make us feel good in a city? Probably not.

The reconstruction of the basics of urban life and city management, taking into account only the technological perspective, will rather lead to the fact that cities will be superficially intelligent and deeply full of injustices and inequalities. This is why, in local government practice and scientific discourse, the second trend of understanding a smart city, which goes far beyond its technocratic perception, is increasingly dominant. In this approach, technological solutions only support a smart city. Thanks to them, it is easier to combine information and a political vision into a coherent programme of improving a city and its services. New technologies are an instrument for creating cities that are able to combine physical and social capital, as well as provide better services and good quality infrastructure. This approach is reflected in the definitions of A. Caragliu, Ch. Del Bo and P. Nijkamp (2011), who write: “We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance”. N. Komninos (2008) also writes: “(Smart) cities as territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management”¹.

A contemporary smart city is a concept that listens to the needs of residents and naturally adapts to them. The technologies operating in a city serve people, providing them with comfort and safety and improving the quality of life. It should be known that although technological solutions undoubtedly make life easier, when they are considered separately from the social context, they do not fulfil their core role. Therefore, R. Robinson refers to the need for mutual realisation of the vision of cities in the future - top-down, implemented by the authorities; and bottom-up, controlled by citizens (Robinson, 2015). If a city wants to be really smart, it has to take into account the needs of all stakeholders. Being smart requires investment in human and social capital. Social participation and the cooperation of public administration with social and business partners with the support of new technologies are very important in order to achieve success. A smart city is a shared space of stakeholders, engaging in the development of ideas and creating innovations (Kauf, 2018).

In the context of the fourth industrial revolution, a smart city can be defined as “an information technology combined with infrastructure, architecture, everyday objects and even our bodies to address social, economic and environmental problems” (Towsend, 2013). A smart city is defined as a city in which ICT is merged with classic infrastructures, coordinated and integrated using new digital technologies (Batty, Axhausen, Giannotti, Pozdnoukhov, Bazzani, Wachowicz, Ouzounis, Portugali, 2012). M. Mitchell defines smart city as

¹ A wider review of the definition of smart city: (Albino, Berardi, Dangelico, 2015).

“intelligence based on the increasingly effective combination of digital telecommunication networks (the nerves), ubiquitously embedded intelligence (the brains), sensors and tags (the sensory organs) and software (the knowledge and cognitive competence)” (Mitchell, 2007). This does not exist separately from other urban systems or connect to them only through human intermediaries.

There is a growing network of overlapping connections from mechanical and electrical systems installed in buildings, through systems embedded in household appliances, transport systems, electricity, water and sewage networks, as well as the safety of city residents.

The presented various definitions of a smart city show that one universally accepted concept of a smart city has not yet been constituted. This is due to constant changes in modern urbanisation that are a consequence of digitisation and the fourth industrial revolution.

3. 4.0 technology and the smart city – relationships and dependencies

Integration of data and technologies in various spheres of life is one of the determinants of smart city development. This makes Industry 4.0 become a reality. The term "Industry 4.0" became publicly known in 2011 when the same initiative was presented (Kagermann, Lukas, Wahlster, 2011) and the "High-Tech Strategy 2020 for Germany" initiative was announced. The key element of Industry 4.0 is the connection of the real and virtual world (Kagermann, 2014; Hermann, Pentek, Otto, 2016), which results in the creation of a new model of urbanisation and a smart city. The model is based on Big Data, Internet of Things, cloud computing or a cyber-physical system. These technologies allow for the technological transformation of a city, but also change the lives of residents (Kupriyanovsky, Bulanča, Kononov, Chernykh, Namiot, Dobrynin, 2016). What's more, Big Data intelligent sensors and analysis enable the transition from Internet of Things to real-time control. Thus, they will support the vision of a smart city which uses the most advanced communication technologies to provide value-added services to city administrations and citizens (Zanella, Bui, Castellani, Vangelista, Zorzi, 2014). Industry 4.0 transforms a smart city into an open innovation platform (Muñoz, Vercher, Muñoz, Galache, Presser, Gómez, Pettersson, 2014) based on a ubiquitous sensor network that meets the requirements of open, associated and trusted platforms.

By using the potential of the fourth industrial revolution, all elements of a city (economy, transport, living, management, education, medicine) can become smarter and can improve the functioning of existing infrastructure and change the approach to planning and urban design. Creating a smart city based on Industry 4.0 will solve some of a city's problems, e.g. in terms of energy efficiency, reducing the arduousness of production processes for the urban environment, making better use of city resources or controlling congestion through an intelligent transport network. Industry 4.0 technology not only allows for vertical integration

of processes (from design, through production to stakeholder service), but also creates conditions for horizontal integration, which goes far beyond the "intelligent factory". It promotes the automatisisation and digitalisation of value creation processes (including public value). Cooperation and partnership are necessary for all stakeholders to benefit from Industry 4.0. A smart city investing in Big Data and developing partnerships with stakeholders will gain the ability to reconfigure the city structure. The wealth of data and networking will make it easier for planners and urban planners to make informed decisions and help city authorities to acquire new, "technologically cleaner" industries. In a smart city which uses the achievements of the fourth industrial revolution, the main driver of development is the advanced technology industry, as well as the creative industry and associated entrepreneurial culture. Such a direction of development requires the concentration of qualified, creative employees and educated residents who are able to create and use the achievements of technology. In a smart city, data platforms will become the basis for a comprehensive digital transformation that will enable identification and adaptation of solutions to specific city problems. It will facilitate partnership with the private sector and allow residents to see and appreciate changes and, most importantly, be their co-creators.

Industry 4.0 allows citizens to become mobile receptors of urban life, take an active part in the life and create a city thanks to their smartphones. Cloud technology and the development of wireless Internet research became the basis for the flow of residents in specific interchanges, adaptation of traffic and intensity of public transport to the needs of residents, as well as for automatically changing traffic lights. Residents of today's cities can use many services on their cell phones, such as buying transport tickets, as well as making comments about the functioning of the metropolis for its authorities. The Warsaw mobile application is a good example. It allows citizens to inform municipal services about defects, neglected vegetation or acts of vandalism. Intelligent transport systems improve urban traffic by providing drivers and the government with information on the current situation on transport routes². Equipment, e.g. bus stops in the interactive scorecard to a Wi-Fi transmitter, allow one to collect information about the number of people and hours of the most intense traffic. Bus beacon equipment³ and a combination of both "digital footprints" allows one to analyse the entire journey of travellers and better adapt the number of public transport vehicles to the needs. Equipping buses with IoT equipment also measurably helps travellers, e.g. in the Google Maps application. It checks the timetables of trains and buses and informs about the changes in real time. As a result, after opening Maps, it shows the exact time in which the means of transport will be at the bus stop.

² An example is the city of Bucheon in Korea, where IBM has installed a camera system combined with software that counts vehicles on the roads. Thanks to them, residents and city authorities could react faster and better to road congestion.

³ These are small devices sending a radio signal and communicating with smartphones via Bluetooth connectors. When we are close to them, they can contact the application on the phone and display the information they need.

Intelligent street lighting control saves energy by adjusting the light intensity depending on the intensity of traffic. This allows one to reduce lighting management costs and electricity costs by up to 40%. An intelligent lighting network can be the basis for intelligent energy distribution in cities. This can be supplemented by an energy management system at home with your own personal computer. This solution allows for continuous monitoring of energy consumption and automatic control of electrical equipment, which allows for planning energy consumption⁴. The combination of these elements leads to the creation of intelligent power networks that are able to effectively integrate the behaviour and operation of all users connected to them – producers, consumers and users who are both producers and consumers. Their goal is to create an economic and sustainable energy system that is characterised by low losses and high quality and security of supply⁵.

To summarise, the use of Industry 4.0 technology allows a city to innovate, and this has a direct impact on the innovation of its residents, companies and institutions based in its area. Thus, the development of a smart city as a city policy goal is conducive to new industrialisation and digitisation of the modern economy. It creates better living, working and education conditions. Industry 4.0 unites a city in a new, innovative way. A smart city based on Industry 4.0, i.e. integrating new technologies, innovative ideas, concepts and solutions, requires cooperation and strategic partnerships. Only then will it be effective and efficient. It will guarantee a better quality of life for residents and will allow cities to meet new challenges. This approach to smart city 4.0 is reflected in the Living Lab, a concept assuming that innovation is created with the involvement of users, in cooperation with city authorities, with residents and the economy sector using new technologies.

4. Smart as a Living Lab

The term Living Lab defines the methodology of innovative research and implementation activities. All innovations (technological and process) are developed, tested and improved in real conditions. The premise of a Living Lab is to create conditions in which innovative products, services or applications developed as a result of cooperation between interdisciplinary working teams and which are implemented in organisations for which they were prepared (Stawarz, Wiśniewska, 2015). For the functioning of a Living Lab, partnership is the key condition; it increases the potential for innovation (the greater the diversity of partners, the more ideas and the greater creativity). Living Lab is a concept that engages one to develop ideas and

⁴ Such systems already exist in Amsterdam and Birmingham, among others.

⁵ In Amsterdam, the system measures, monitors, controls and optimises energy flows in the network (from renewable and conventional sources). It provides the ability to quickly locate faults in the network. It is based on a system of electronic sensors connected through a network that is associated with special software.

create user innovations at particular stages of the process, i.e. discovering new products, prototyping, validating and improving them (Lama, Oigin, 2006). It is important to involve the widest possible range of stakeholders (residents, entrepreneurs, tourists, local government officials, etc.). This is reflected in the conclusion of partnerships, which are usually public-private. Thus, a Living Lab is, as it were, an environment of open innovation in everyday life conditions, focused on the joint creation of innovation generated by users and stakeholders.

The Living Lab examines the impact of digital technologies on the functioning of a city and its inhabitants, as well as the reactions of users on the functioning of ICT systems, which allows for more efficient implementation of new solutions (Wiśniewska, 2015). Buildings with apartments, offices, shops, services, coworking rooms, meeting areas, generally everything that is related to life, work and rest in the city. The tests will cover not only buildings, but also open public spaces: squares, streets, parking lots, rest areas. The focus of a Living Lab is always a person/resident who can test all solutions. The purpose of a Living Lab is to show, on the example of a small environment, what the solutions of the fourth industrial revolution are for and what value they can bring to all groups of stakeholders. In Poland, such a centre is being built by the Warsaw University of Technology in alliance with Pro Development and other partners. It is creating a new campus, which is to be an incubator and testing ground for new smart technologies serving city residents. The idea is to create a space in which designers, engineers, entrepreneurs and researchers will co-create and test solutions for real users in real conditions. The construction is expected to be completed by 2020. It will be a piece of a real city, where residents, scientists and entrepreneurs jointly create, test and improve technologies in a real-life smart living area.

Asseco Innovation Hub is being created in Rzeszów, which is to be a place for conducting advanced research and development works. Their goal will be to create proprietary technologies and IT products, including for the energy, telecommunications and media industries, healthcare, banking, agriculture, enterprises and public administration. Projects related to broadly understood IT security will also be developed here. The research will focus on the most important phenomena and trends from the world of new technologies, such as: Internet of Things, telemedicine, electromobility and intelligent power networks. Asseco Innovation Hub will also cover artificial intelligence solutions, including self-learning systems based on so-called machine learning. Thanks to advanced data analysis collected in real time from various sources, the system will identify what the user is doing and how it can, for example, protect him from danger.

In Sondgo, South Korea, programmers and scientists created the city using the latest technologies. This city can be considered a functioning innovation lab, which is to make the lives of its inhabitants more convenient and safer while saving energy and resources. The measurement data necessary for the proper functioning of the city flows to a highly efficient data centre. The creators' idea was to build a city that would use one third less energy and resources compared to other urbanised areas. Sondgo is a modern business space and one of the

first cities built from scratch according to modern urban planning. It should be environmentally friendly and guarantee people work near their homes in order not to waste time on travelling.

Residents of the futuristic city, thanks to live broadcast cameras installed in the city, can enjoy outside views without leaving home. No keys are needed to enter the apartment, just the touch of a fingerprint on a reader on the door handle or using a card. The lights and blinds in all rooms are controlled by means of an intelligent wall panel or a smartphone application. At intersections with traffic lights, cameras send recorded images to the traffic control centre, thus informing about the current traffic on the road. Sensors built into the street light the lanterns only when someone is actually walking on the sidewalk. The sensors measure where a lot of electricity is currently consumed or what lighting and heating needs are necessary in a given place due to the number of people staying there. Detectors also measure the content of harmful substances in the air. When a fire breaks out, the sensors trigger an alarm by automatically sending a signal to the fire department and emergency services. Displays on subway platforms and bus stations provide real-time information about arrival and departure times of means of transport.

Currently, Sondgo is considered to be the first smart city based on the technology of the fourth industrial revolution and a model of the urban future.

5. Conclusion

The concept of smart city has evolved considerably in recent years, from its strictly technological understanding to the concept of listening to the needs of stakeholders, in which technologies serve residents and make their lives easier. However, with the growing scope of the impact of digitisation on city life and urbanisation processes, the importance of technology as a factor in the creation of city intelligence is growing. Industry 4.0 (Internet of things, cloud computing, cyber-physical systems, Big Data, etc.) determines the planning processes of urban housing (smart home), production and business (smart factory, smart economy) and management processes (smart management) and creates conditions for the development and accumulation of social capital (smart people/population).

Industry 4.0 technologies create a new space for a city and its infrastructure. At the same time, they create new opportunities to solve the problems of a city's functioning, i.e. more efficient use of resources, energy efficiency, as well as traffic management in the city. The city lab is a reflection of a smart city in the age of the fourth industrial revolution. It is an environment of open innovation in everyday life conditions, focused on the joint creation of innovation by all groups of stakeholders. The long-term nature of a Living Lab can be a systemic solution to the problems of modern cities of the 21st century, such as Sondgo.

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