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THE SIGNIFICANCE OF THE SMART CITY CONCEPT FOR CREATORS OF BIG DATA SOLUTIONS

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Purpose: The main purpose of this article was to research how is the concept of smart cities perceived by IT developers involved in programming Big Data solutions, as well as to highlight their opinions concerning the relation between Big Data technology and creating a smart technological and business environment.
Design/methodology/approach: The theoretical part of the article presents the issue of a smart city. The issue of Big Data in the context of the functioning of contemporary cities was also discussed. Empirical research was carried out using an online survey among participants who are employees of the IT industry.
Findings: The conducted research constitutes the first step in assessing the relations between modern cities and their users and creators. Employees of organizations dealing with Big Data technology are familiar with the basic assumptions of the smart city concept. However, a problematic issue consists in identifying the impact of this concept on the life and immediate environment of the research participants.
Research limitations/implications: The main research limitation consists in the number of analysed surveys. In the case of more feedback, the research sample could be even more reliable, which in turn can lead to extensive conclusions.
Social implications: Publishing the article may contribute to raising the awareness of Big Data developers concerning their contribution to building and developing smart solutions.
Originality/value: The contribution of the research to determine how smart cities impact their users and creators. The article is addressed to all stakeholders of modern cities, including primarily local governments, citizens, enterprises, as well as research and technological units.

Keywords: Big Data, decision-making, IT developers, smart cities impact.

Category of the paper: Research paper.

1. Introduction

The progressing technological and social development requires using innovative solutions to meet the challenges faced by modern cities. The available information indicates that 55% of the world's population lives in cities, while forecasts show that by 2050, 68% of the global

population will be living in urban areas, and this trend is going to become stronger (United Nations, 2019, p. 1). It is expected that dynamically progressing urbanization driven, among others, by economic factors will constitute one of the main factors intensifying problems related to environmental pollution, high energy demand, private transport, availability of infrastructure or public transport (Ministerstwo Cyfryzacji, 2019, p. 34). Due to this, plans are being drawn up worldwide to ensure the sustainability of both existing and developing cities. Effective city management, taking into account the long-term needs of the residents, can become a source of benefits from the development of urban units. This has resulted in an increased use of modern technologies in tackling complex problems, which in turn contributed to popularizing the concept of smart cities.

An important aspect of the functioning of cities is the generated data. It is estimated that, in an overall manner, expenditure on digital information in Poland amounted to USD 32.1 million in 2020, which means an increase of 17.5% when compared to 2019 (Figure 1). This leads to the conclusion that the pandemic and its unpredictability motivated Polish companies to invest in Big Data. These figures mainly include expenditure on data used in automated advertising as well as the costs of information processing, including data management platforms. Analysts assume that the value of the global and Polish data markets will constantly increase (Marzouk, Othman, 2020, p. 121).

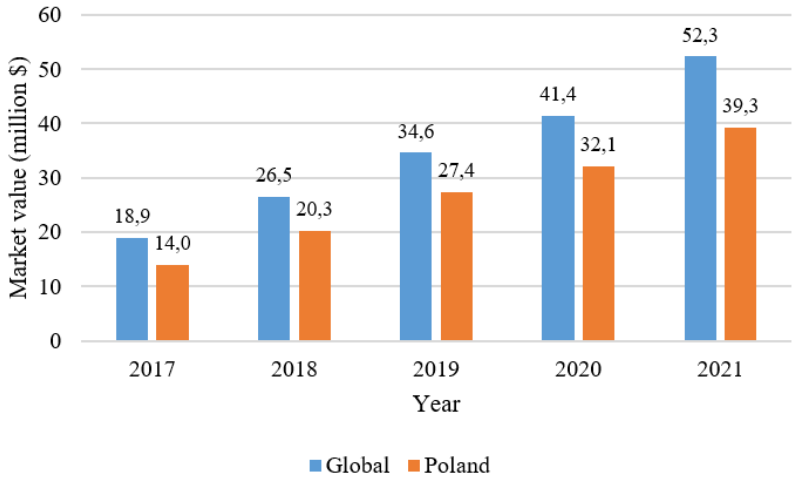

Figure 1. Value of the data market in the world and in Poland in 2017-2021. Source: own elaboration based on Report Global Data Market Size, pp. 8, 18.

A condition necessary for the real development and implementation of the concept of a smart city is to undertake a joint effort by people from various disciplines, i.e. engineering, architecture, urban design, economics, etc. (Ahmad et al., 2022, p. 1). Due to the observed trend of ubiquitous digitization, IT specialists constitute an important professional group for developing modern cities, the demand for which will constantly increase around the world. According to the 20th edition of the State of the Developer Nation report, there were 26.8 million active programmers in the world at the end of 2021. Experts predict that the number of developers will increase to 45 million by 2030 (State of the Developer Nation, 2021).

2. Smart city concept

The smart city concept finds application in virtually all fields of research concerning a modern city, as well as in the issues of related disciplines. The meaning of the word smart includes a wide range of options regarding its interpretation, thanks to which the spectrum of its applications is almost unlimited (Tota, 2017, p. 5; Cocchia, 2014, p. 17). Although the concept of a smart city is extremely broad and popular, there is no universal and unambiguous definition. This is mainly due to the fact that the components of a smart city have not been clearly established so far. In recent years, a number of attempts have been made to define this concept in a coherent way. The term smart city found in literature sources distribute the emphasis in various ways, often focusing to different degrees on various spheres of the city's functioning. One of the most popular approaches to the concept of a smart city is to consider it through the prism of six areas, which include: economy, transport, environment, people, quality of living, and smart management (Table 1) (Rubisz, 2020, p. 239).

Table 1.
Main areas of a smart city including determining factors

Area	Determining factors
smart economy	entrepreneurship; innovation; labour market flexibility; position in the national and international economy; ability to adapt to upcoming changes
smart mobility	local and international accessibility; accessibility of infrastructure; ICT; sustainable, innovative, and secure transport systems
smart environment	attractiveness of natural conditions; level of environmental pollution; environmental protection; sustainable methods of resource management
smart people	level of qualifications; lifelong learning; social and ethnic diversity; creativity, openness, participation in public life
smart living	existing cultural facilities; living conditions (health, safety, housing); educational institutions; tourist attractiveness; social cohesion
smart governance	transparent city management; social participation; level of public services; implementing development strategies

Source: own elaboration based on Rozpondek, 2021, pp. 14-15.

In the initial vision, smart city stood for a concept in which using technology was aimed at achieving efficient results in the field of energy economy and reducing CO_2 emissions into the atmosphere (Stawasz, Sikora-Fernandez, 2016, p. 7). At the beginning of the 21st century, a dynamic increase in interest in the smart city concept began, as a result of which many approaches in terms of establishing the conceptual framework of a smart city have been formulated. The diversity in terms of individual views results, for example, from using a diverse perspective in describing phenomena (e.g. scientists, business people) or attempting to analyse them in relation to various fields (e.g. urban planning, economics, sociology, etc.). The common determinant of a smart city observed in many views is the aspect of a creative society, whose actions are undertaken using technical and technological innovations, as well as information and communication technologies (Korenik, 2019, p. 19). In their definitions, many authors also emphasize the extensive specificity of investments and manners of managing a smart city by

summing up technological and information elements with economic, socio-cultural, and organizational development (Daszkiewicz, 2015, p. 264). In reference to legal regulations and other regulations, the ISO 3720:2014 standard constitutes a set of standards determining the concept of a smart city in relation to acts of international law. This document constitutes the result of joint activities of the European Union Standards Organisations and the Geneva Standards Organisation, as well as the national bodies for standardization. However, the developed standards are not mandatory, as they do not have a legal nature (Korenik, 2019, pp. 22-23).

Smart cities are constantly evolving and undergoing dynamic transformation. It is assumed that there are three stages of smart city development, named as smart city 1.0, smart city 2.0, and smart city 3.0. In the first generation, technology and communication companies show a high initiative. They offer their products and services to local authorities in order to achieve greater efficiency in city management, however, not being fully aware of the benefits and potential risks. The second stage of development focuses on the fact that urban authorities are the initiator of change, choosing technologies and solutions that they consider to be beneficial for the city. In the third generation, the implemented solutions respond to the problems of residents and are consulted with them. Technology and business are becoming less significant, and priority is given to participation and solving specific problems reported by residents in a way that is appropriate to them (not necessarily using the latest technologies) (Szczech-Pietkiewicz, 2018, pp. 245-247).

3. Big Data in contemporary cities

Along with technological development, smart devices and objects equipped with various types of sensors began to affect the lifestyle of city residents, and all actions undertaken by the society transformed into large, irregular, and diverse data sets (Sun, Wu, 2019, p. 663), which can be described as Big Data. Collecting and developing this type of data is a difficult process, and at the same time extremely valuable. Storing, managing, and analysing this data is not possible using commonly available methods, but taking advantage of advanced solutions, they lead to new and useful information (Zhang et al., 2022, p. 2). Therefore, the concept of Big Data should be considered not only through the prism of data sets, but also as a combination of techniques enabling their processing and analysis. In the initial phase of developing the concept of Big Data, its three main attributes were provided, constituting the so-called 3V model, i.e. variety, velocity, and volume. As the term developed, new dimensions (value, variability, veracity) were added, which in turn led to creating the 6V model (Rozpondek, Pachura, 2020, pp. 20-21).

Sources of Big Data in reference to a city can be divided into five types: data from urban infrastructure sensors and moving objects, data generated by the public, administrative data, data concerning customers and transactions, as well as art and humanities data. The Table 2 presents examples and user groups for designated sources.

Table 2.
Big Data sources in the city

Source	Example	User group
data from urban infrastructure sensors and moving objects	A sensor system for environmental, water, buildings, and transport management; Internet of Things	Public and private municipal and management organisations, independent ICT developers, engineering researchers
data generated by the public	Participatory sensing system; using of social media and online social network; global positioning system (GPS)	Private companies, customer-focused public organisations, independent programmers, researchers of data science and urban social sciences
administrative data	Public administration data concerning transactions, taxes, and revenues, payments, and registration; basic public data concerning employment, health, social benefits, education	Open data: innovators, hackers, researchers. Confidential data: government data agencies, urban social scientists involved in economic and social policy research, public health and medical researchers
data concerning customers and transactions	Data concerning customer transactions coming from business documents; user data from public utility and enterprises and financial institutions; product purchases, and service contract terms	Private enterprises, public institutions, independent developers, and researchers of science concerning data and urban social sciences
data concerning art and humanities	Text, image, sound, video, language data, film, culture, digital objects, and other media	Urban designers in the field of history, art of architecture, and digitization; private and social organizations; data programmers and scientists

Source: Thakuriah, Tilahun, Zellner, 2015, p. 7.

Data collected as a result of actions undertaken in a city provides comprehensive information reflecting the real state of its operation. Traditional data processing technologies often prove insufficient in order to obtain an in-depth level of information from it. It is necessary to implement precise collection, storage, and processing of large data sets, which will make the obtained information useful in developing the smart city concept. In the era of Big Data, building a smart city cannot be based solely on the computerization and digitization of various data sources, but primarily on smart data analysis allowing to obtain useful information supporting the decision-making process on their basis (Sun, Wu, 2019, pp. 664- 665). Such effectiveness constitutes a factor stimulating cooperation and communication between stakeholder groups, which results in developing innovative solutions. The use of Big Data finds its application in almost every field of a city's functioning, including units called smart cities. Big data allows a city to obtain innovative and valuable insights from a vast amount of data obtained from various sources, which in turn support decision-making processes, promote sustainable development, and provide innovative services improving the quality of living for citizens. This technology contributes, for example, to improving the quality of public services, informing about how to manage environmental pollution, or promoting public safety (Zhang et al., 2022, pp. 2-3). Data network infrastructures linking parking systems, traffic lights,

municipal buildings, smart measuring systems, and electric vehicle charging stations support citizens to quickly locate free parking spaces, work in favour of optimal energy consumption or adapting the street lighting system to weather conditions (Rozpondek, 2021, p. 82).

4. Description of the research method

The empirical research has been carried out in May and June 2022 among people working in IT organizations. The surveys were conducted using an online tool consisting in Google Form. Due to the need to systematize a wide spectrum of analysed issues, the research was divided into two main areas – the first one concerning the concept of a smart city, and the second one concerning the relation between a smart city and Big Data. In order to obtain fair and reliable results, the research participants were granted total anonymity. A total of 42 responses of participants were selected for the research analysis. The Table 3 presents basic information concerning the target group of respondents.

Table 3.
Basic information concerning respondents

Information about respondents		
Feature	**Number**	**Share**
Gender:		
Female	2	5%
Man	40	95%
Age (in years):		
18-24	5	12%
25-29	21	50%
30-34	13	31%
35-39	3	7%
Activities related to projects implemented by respondents in their professional work:		
Medicine, pharmacy, healthcare	14	33%
Trade, E-commerce	12	29%
Banking	9	21%
Insurance	7	17%
Cities with which the respondents are associated:		
Warszawa	19	45%
Wrocław	10	24%
Gdańsk	6	14%
Poznań	4	10%
Częstochowa	3	7%

Source: own elaboration based on research results.

The first criterion that was adopted to create the target research group was determining whether the professional work of a given person is related to the programming of solutions in the field of Big Data technology. The second criterion consisted in determining whether the city with which the respondent is associated is considered smart or whether it implements innovative initiatives into its structure.

5. Results and discussion

During the first stage, the issue of understanding the concept of a smart city in the surveyed group of respondents was analysed. The obtained results showed that more than half of the respondents say that they are aware of the concept (5% of them declare their state of knowledge as "very good", 12% as "good", and 38% as "rather good"). However, almost one third of respondents assess their knowledge concerning the assumptions of the above-mentioned idea rather poorly (19% of them declare their state of knowledge as "rather poor", 5% as "poor" and 5% as "very poor"). In the following question, the respondents exchanged the keywords, which in their opinion make up the definition of a smart city. The set of designated phrases underwent a quantitative analysis with the use of the so-called word cloud, which allows illustrating which of the keywords appear most often in the provided answers (Figure 2). The size of the individual words forming the cloud reflects the frequency of their occurrence. Taking advantage of a generator for creating word clouds, the frequency of assigning specific attributes to the smart city concept was identified.

Figure 2. Word cloud of the main issues related to the concept of "smart city".

Source: own study.

When analysing the presented cloud of elements constituting the definition of a "smart city", the following observations can be made:

- Persons providing the definitions agree that a smart city is an entity, which in its operation and development takes advantage of modern technologies allowing to combine different urban systems and stimulate innovation facilitating implementing urban policy objectives. The obtained results also show that the idea of Smart City is inextricably linked with the so-called Internet of Things (IoT), which bases on a network of interconnected smart devices that can collect, process, and exchange information through an electrical or computer network.

- Next, the most frequently identified issues were those that together make up transport and urban infrastructure. Respondents paying attention to these aspects may suggest that improving the flow of traffic or increasing the comfort of movement significantly affects the comfort of living and staying in the city.
- It is surprising that the answers did not include the concept of "data" or "Big data", which are an integral part of the functioning of cities. Perhaps they were not exposed due to their overly general nature, and they were included by the respondents in other, more detailed issues.
- Phrases indicating issues related to human capital were mentioned relatively rarely. One of the reasons for this could be that people are present in every place and at every level of a city's functioning (both as providers and as recipients), and that is why the human aspect was considered as obvious.

The following question in the conducted research concerned assessing the smartness of cities with which respondents are associated. An analysis of the answers shows that only 31% of the respondents chose the "rather yes" answer, and 19% of them chose the "hard to say" answer. Half of the respondents do not have a positive opinion about the smartness of the city with which they are associated (31% of "rather no" answers, 12% of "no" answers, and 7% of "definitely no" answers). However, according to the available rankings and lists, cities related to respondents are actually considered smart or innovative. In the Smart City Index 2021, Warsaw was listed as 75th (Smart City Index, 2021, p. 8). Whereas, in the IESE Cities in Motion Index 2019, this city ranked 69th among the capitals of innovation and advanced technologies, reaching the CIMI index of 60.13, and Wrocław ranked 95th with a score of 53.39. In comparison, the CIMI for London, the leader of the ranking, was 100 (Berrone, Ricart, 2019, p. 26). According to the analysed classification, among the aspects that make up the quality of life in a city, social cohesion deserves the greatest attention in both Warsaw and Wrocław, while areas such as human capital, city management, technology, and the environment should be improved.

Wrocław is a laureate of many awards in the field of smart solutions. One of them consists in the 2018 Green & Smart City Awards received at the global Smart City Expo in China in the category of Top Level Design. During the Smart City Forum, Wrocław received recognition in the category of 2018 city of over 500 thousand residents for innovative projects in the field of electromobility. Whereas, in 2016, in the same category, it received the award for taking action towards formulating Wrocław as a Smart City based on key elements, i.e. strategy, residents and communicating with them, attractiveness of living, as well as development and creativity, expressed, for example, in open data and promoting the startup environment (Knight, 2018, p. 7). Poznań won the Smart City 2019 Competition. The jury distinguished the capital of Wielkopolska for implementing the idea of a smart city, taking advantage of innovative solutions, and effectively managing resources and the development strategy for improving the lives of residents in the field of transport, infrastructure, energy, spatial management,

and the environment. The Tri-City (Gdańsk, Gdynia, Sopot) received the Human Smart City 2019 award for the example of cooperation and harmonious development of the entire metropolitan area, by making the best use of the potential of member states and municipalities, respecting their distinctiveness and specificity (smartcityforum.pl). Gdańsk, Wrocław, Poznań, and Częstochowa have also been recognized as the most innovative cities in Poland according to a Forbes 2019 ranking (Forbes.pl).

In the following step, based on the characteristics of smart city 1.0, smart city 2.0, and smart city 3.0 included in the survey, the respondents were asked to determine the degree of development of the city with which they are associated. The second degree of city development was indicated by 95% of respondents, and the remaining answers indicated the third degree. This result confirms the observations of other authors (Szaja, 2018, p. 351; Legutko-Kobus, 2021, p. 76) that most Polish cities should be classified as second-generation cities. The following question, in which the respondents had the opportunity to choose many answers, concerned the benefits that cities achieve by implementing the concept of a smart city into their activity. According to research, the most significant thing is to change the manner of managing traffic lights and city lighting, while the least chosen response was to increase the level of health care. These results confirm the previously cited examples of using Big Data in cities. The Figure 3 presents detailed data.

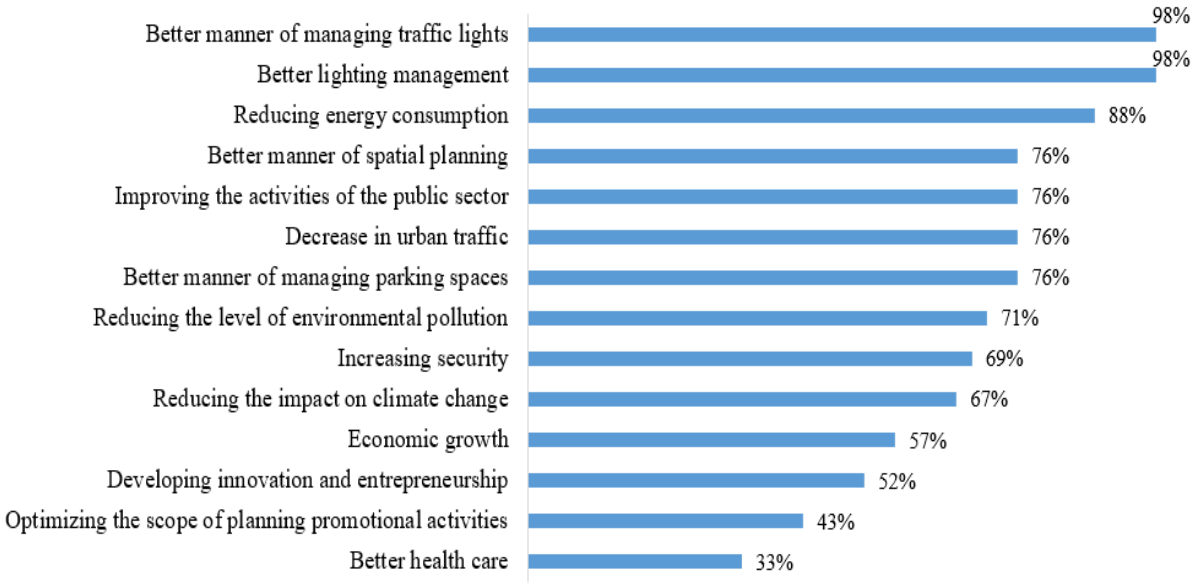

Figure 3. The benefits that cities achieve by implementing the concept of a smart city into their structures.

Source: own study.

The second area of the conducted research concerned the issue of Big Data and its connection with the concept of a smart city. The first question showed that 69% of the respondents do not feel responsible for building and developing a smart city by working in the Big Data analytics industry, 19% of them answered "hard to say", and only 12% of the respondents had a positive opinion concerning this relation.

The respondents also assessed the impact of Big Data and smart city analytics on decision-making and shaping business strategies. The research shows that 93% of respondents believe that both Big Data analytics and actions undertaken in terms of a smart city affect the functioning of enterprises (Figure 4).

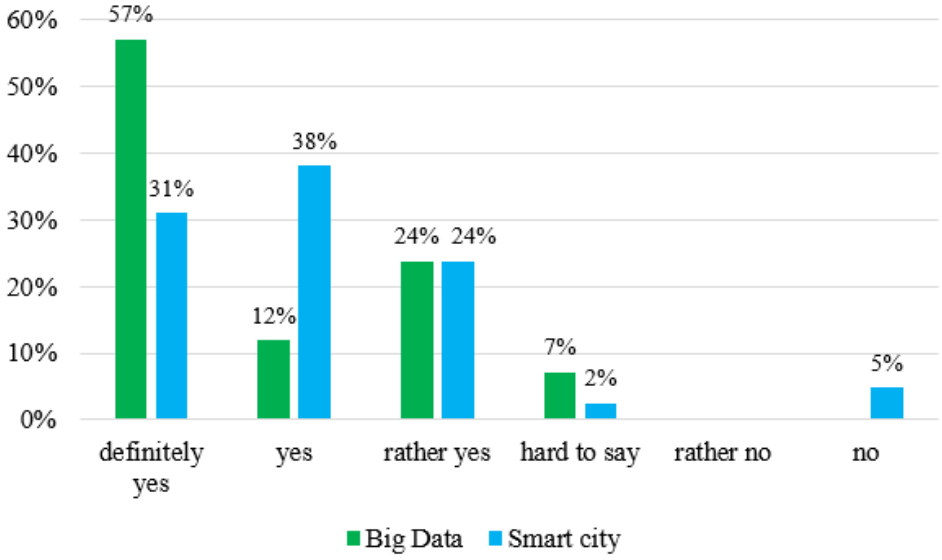

Figure 4. Impact of Big Data and smart city on decision making and business strategy shaping.
Source: own study.

In the following step, the respondents assessed the possibilities of applying Big Data analytics in individual areas of a smart city's functioning. In order to better familiarize the respondents with the analysed issues, examples illustrating its essence were provided for each of the categories. According to research most people point to the use of Big Data in smart mobility (88% of respondents in total) and smart environment (81% of respondents in total). In turn, the area where, according to the respondents, the possibility of applying this technology is the smallest consists in smart governance (a total of 50% of responses indicating the applicability, and 31% indicating its lack) (Figure 5).

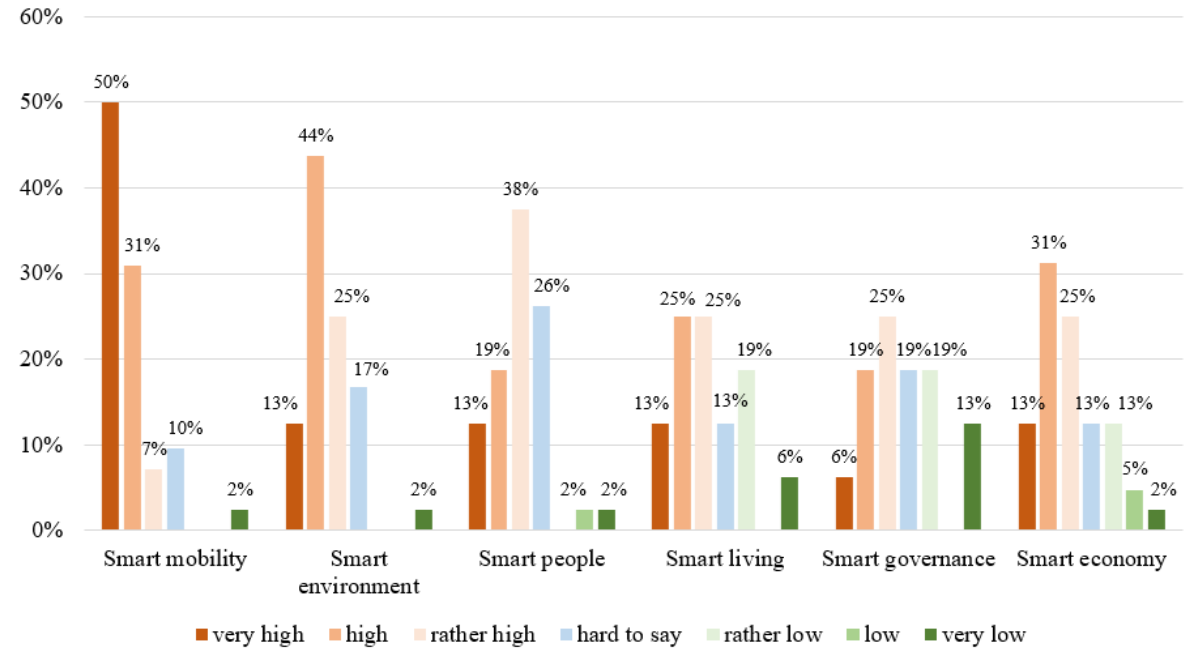

Figure 5. General assessment of using Big Data in smart city areas.

Source: own study.

The conducted research also shows that only 13% of respondents declare the impact of the concept of a smart city on the functioning and development of the company in which they currently work, 50% of them have problems with determining the level of impact, and 37% of respondents do not see a connection with this aspect.

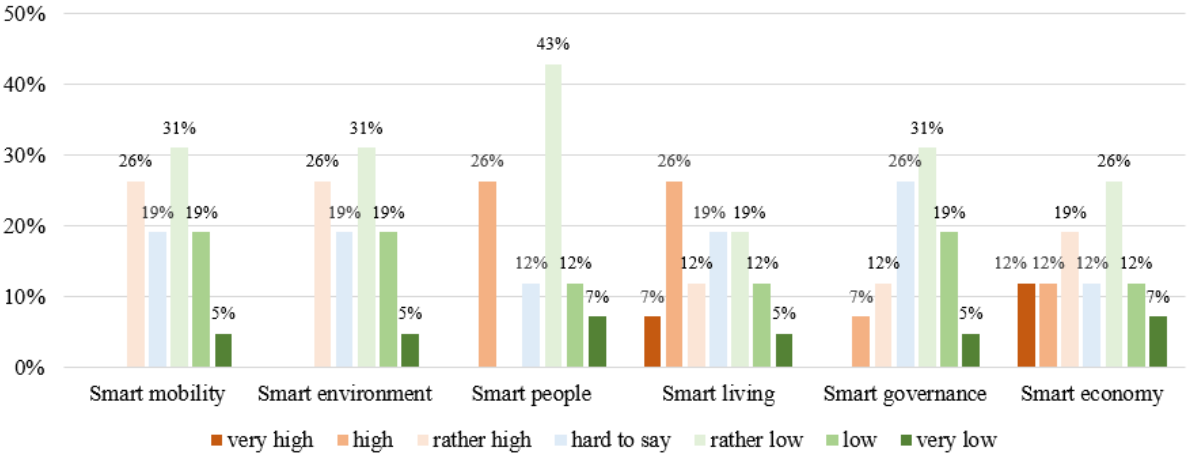

Figure 6. Assessment of the impact of individual areas of a smart city on the functioning and development of the company.

Source: own study.

The obtained outcomes are confirmed by results in which the significance of specific areas of a smart city was assessed in terms of the dynamics of companies associated with the research participants (Figure 6). More than half of the respondents do not see a relation between smart mobility, smart environment, smart people, and smart governance and the functioning and development of the company in which they work. Only in the area of smart economy

(43% of the total answers indicating "yes", 45% for "no") and smart living (45% of the total answers indicating "yes", 36% for "no"), the respondents provided answers with a similar quantitative distribution.

6. Summary

The aim of this article was primarily to research how the concept of a smart city is perceived by Big Data employees, as well as to reveal their opinions concerning the relation between Big Data technology and creating a smart technological and business environment. An attempt was also made to determine how a smart city affects the functioning of companies with which respondents were associated. Proper analysis and interpretation of the ever-growing amount of data play an important role in the development of each city, and many processes are directed towards complete optimization and automation. This trend is reflected in the growing professional group of IT specialists who are also residents and experts in the development of smart urban solutions technologies. Due to this, the participants of the research consisted in people involved in programming solutions in the field of Big Data, who generally have little experience in the field of the smart city concept. Turning to a group, which is not an expert in this topic, intended to obtain an objective image of the analysed issues. It is worth mentioning here that 100% of the participants who decided to complete the survey were between the ages of 18 and 39. This result shows that young people are probably more interested in new trends concerning programming, as well as current issues related to the functioning and development of cities.

Research results show that the respondents understand the concept of a smart city and notice the benefits of implementing this concept into urban structures. Even though the professional work of the respondents is related to Big Data, they do not feel as the creators of smart solutions. The respondents notice the practical application of Big Data analytics in the areas of city functioning (primarily in smart mobility and smart environment), but do not declare the impact of a smart city on the development and making business decisions of the companies in which they work. One of the reasons for the observed situation consists in the sole openness of the society to understanding issues aimed at facilitating living. This is also confirmed by the results of the Digital City Report, where representatives of local governments and residents indicate that an important barrier when implementing smart solutions in cities consists in the poor awareness of the public concerning the benefits of such projects. Furthermore, most implementations in Poland consists in individual actions, which are very often implemented on an ad hoc basis, but still fit into the definition of a smart city. A city constitutes a complex system that only as a whole can adapt to the dynamically changing conditions of the environment. Its efficient operation is based on harmonious activities based on clearly defined

goals included in the assumptions of multifaceted development. An important issue in this area consists in engaging in dialogue and cooperation between individual representatives of an urban society. Formulating own beliefs and opinions by individuals, while actively participating in the city's development, constitutes the foundation for creating a modern space based on the creative potential of its inhabitants.

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