

CONCEPTUAL FRAMEWORK FOR MEASURING AWARENESS AND NEEDS OF CITY RESIDENTS TOWARDS A SMART CITY

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Introduction/background: The level of residents' awareness of the Smart City concept and their approach towards the potential of Smart City dimensions requires a more detailed investigation. The research tool prepared in this article may have an interesting impact on the residents of developing cities. The framework will allow researchers to examine the knowledge of residents about the Smart City concept, and may contribute to the identification of new social needs among city' inhabitants.

Aim of the paper: The main objective of this paper is to define the Smart City as a community-driven phenomenon and determine the current trends in case of Smart City dimensions. Authors undertake the task of synthesizing all dimensions mentioned in the literature about the Smart City concept. Additionally, the paper presents a conceptual research framework that may be used as a research tool in order to measure the level of residents' awareness of the Smart City concept.

Materials and methods: A comprehensive desk research was conducted which included iterative analyses of Smart City literature and Smart City models. A research framework, in form of a questionnaire, was prepared in order to gather qualitative and quantitative data about awareness and needs of residents towards a Smart City. The findings concerning the Smart City concept, that were presented in the article, will require further verification – both in terms of empirical research and further literature analysis, due to the dynamic development of this particular issue.

Results and conclusions: The Smart City concept has many definitions and domains that are often perceived from the perspective of the investigated issue. This paper synthesizes all the dimensions mentioned in the available literature and adds new ones as well. Moreover, the preliminary research results indicate that the awareness of the Smart City phenomenon among residents of a developing town is quite high. Research results may be of great interest for the authorities of a particular city. Therefore, the presented framework may induce communication between local communities and city authorities.

Keywords: Smart City, Awareness, Smart City Dimensions, Smart City Domains.

1. Introduction

Progressive urbanization processes have gradually contributed to the establishment of an increasing number of large-scale urban agglomerations with high density of population. The rapid expansion of urban and residential territories, including living areas around towns and newly emerging networks of large cities, has created a number of serious problems such as (Riffat et al., 2016): excessive consumption of all kinds of resources, high level of air pollution and regular occurrence of smog, severe traffic jams, passengers overload in public transport, problems related to waste management and water resources management, excessive consumption of electricity and energy, problems with accessibility of services, issues associated with meeting social needs in terms of tourism, issues related to medical care services. In order to prevent these growing and unfavorable issues, the concept of intelligent cities called Smart City has emerged in the last two decades, in which modern communication and information technologies (ICT) and advanced devices are being used to solve complex problems (Stawiasz et al., 2012). These technologies, that are usually being used in a Smart City, may include the following solutions (Lu His-Peng et al., 2019):

- *Internet of Things* – an integrated network of receivers, sensors and cameras that are closely interconnected and combined with other devices for a specific purpose.
- *Big Data Analyses* – systems which are collecting and analyzing massive amounts of data to find better solutions or valuable information.
- *AI Systems* – artificial intelligence algorithms and neural networks (e.g., application of intelligent road intersections and crossroads that are aware of the traffic situation).
- *Cloud Computing* – application of cloud computing technology.
- *Community-driven apps* – autonomous mobile applications and advanced software used to support residents and tourists visiting the city with a variety of services to meet social needs.
- *Advanced IT platforms* – consisting of all types of necessary hardware and software that also supports all of the technologies mentioned above.

The aforementioned technologies can be considered as some of the basic attributes and features of Smart Cities. Therefore, the Smart City can be defined as a system that integrates the layers of city authorities and city residents in order to launch and develop intelligent economy, intelligent mobility and transportation, intelligent living spaces, smart society and smart management of city resources (Bruneo et al., 2019). Usually, the *intelligent* or *smart* adjectives stand for self-aware, evolving and adjustable to the dynamically-changing surroundings. This is just one of the many definitions of Smart City that can be found in international scientific papers. In general, the entire concept aims to meet the sophisticated needs of city residents, to guarantee them a better quality of life and, above all, to develop cities according to the trend of *smart growth*, which is based on the optimal management of resources.

Furthermore, the idea of Smart City encourages local residents to develop a greater commitment towards the local society they are currently living in.

The main objective of this paper is to describe the development of a research tool in the form of a questionnaire that can be used to measure the awareness of Smart City concept among city residents. Also, the suggested research framework can be used to identify the social needs of city inhabitants which could be met by the implementation of modern technologies within the Smart City concept in the fast-growing cities. In addition, authors of the paper describe the proposed research methodology, attempt to determine what a Smart City actually is, and conduct an overview a few interesting examples of modern ICT solutions which were used in various Smart Cities located in USA and Europe.

2. How to Define a Smart City? Overview of Smart City Interpretations

Smart Cities have many terms or descriptive attributes and are usually referred to as *knowledge city*, *information city*, *virtual city*, *digital city*, *eco-modern city*, *innovative city*, *intelligent city*, *creative city*, *self-developing* and *self-learning city*, *green city*, *social-oriented city* (Finger, 2018). All of these approaches regarding the perception of Smart City are, in most cases, dependent on the type of problem which is being described and the point of view of a particular group of researchers. Thus, there are many nomenclatures, names, and epithets that attempt to reflect the proper context of the Smart City concept (Hollands, 2008). Perhaps the most accurate description that captures the general idea of the Smart City phenomenon, from the point of view of management and economics, seems to be the widely used ‘*Smart*’ adjective. However, even the common term of Smart City has its own genesis (Pardo & Nam, 2011), that is, in the past it was described as a combination of a knowledge society (also known as knowledge-based community) and a digitalized city. The latter stands for a city in which a high level of digitalization of services and technologies was implemented in order to increase effectiveness of city-related processes and activities (Deakin, Al Waer, 2011). The term of digitalized city was quite popular in the 90-ties and was rather related to one aspect, namely the development of ICT and digital services within a specific city (Dameri, Cocchia, 2012). The term Smart City became more fashionable around 2009 as a result of the expanding awareness of knowledge-based community, as well as the increasingly popular concept of sustainable development (Eremia et al., 2017). Regarding the latter aspect, the Smart City should not be confused with the concept of sustainable-developed cities as an empirical study conducted in 2017 has revealed (Ahvenniemi, 2017). The Smart City concept puts more emphasis on the social benefits of improving the quality of life economically and culturally. On the other hand, the concept of sustainable development mainly focuses on optimal use of resources and environmental protection.

Table 1 presents a summary of all the most popular definitions of Smart City that have appeared in the scientific literature over the last 20 years. As shown in Table 1, most authors of Smart City definitions emphasize that the quality of life of residents and the use of complex systems based on different types of ICT technologies are usually considered as one of the key objectives or even hallmarks of an intelligent city. The definitions often include statements such as: *increased efficiency, ICT, integration, increased awareness, increased accessibility, optimal use of resources* or *ability to solve social and public problems*. From the point of view of the research tool developed in this paper, it is quite difficult to choose just one proper definition of Smart City. Each definition has some important elements or highlights particular Smart City domains. Therefore, defining Smart City is a challenge due to the broad and complex meaning of the entire concept that can encompass different areas of management, such as project management, public management, technology management, public space management, innovation management, knowledge management, environmental management and many other areas. Nonetheless, it is important to emphasize that by the intelligence of a city, most scholars refer to the ability of community-driven development (Albino et al., 2015) and fulfillment of needs of most residents. Taking into account the number of different definitions, verifying residents' awareness of the Smart City concept can be quite a challenge. Some scholars have even decided to develop a taxonomy of Smart City definitions, in which they distinguish different categories that reflect general perceptions of the concept: technology-based definitions, domain-based definitions, definitions based on the integration of the system, definitions focused on the data gathering.

On the other hand there are scientific studies on defining the Smart City concept that highlight the frequent lack of the satisfaction aspect of local communities (Prado, Da Costa, 2016). Prado and Da Costa reveal that definitions available in the scientific literature have limited scope, and in most cases are only focused on strategic actions from a city perspective instead of concentrating on social aspects and happiness of citizens. Also, other articles point out that the trends towards Smart City are gradually changing and Smart Sustainability will become even more popular in the upcoming years than the Smart City concept itself (Stübinger, Schneider, 2020). Smart Sustainability can be defined as the usage of modern ICT in smart urban areas (and associated layers) in order to achieve a sustainable development, which consists in fulfilling the needs of current communities without sacrificing the needs of future generations with respect to economic, social and environmental aspects.

Table 1.
Overview of various definitions of Smart City concept

Overview of most popular Smart City definitions	
Authors of Smart City definition	Content of particular Smart City definition and general interpretation
Hall, R.E. (2000). The vision of a smart city. Proceedings of the 2nd International Life Extension Technology Workshop (Paris, France, Sep 28).	<i>A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.</i>
Partridge, H. (2004). Developing a human perspective to the digital divide in the smart city. Proceedings of the Biennial Conference of Australian Library and information Association (Queensland, Australia, Sep 21-24).	<i>A city where the ICT strengthen the freedom of speech and the accessibility to public information and services.</i>
Giffinger, R. et al. (2007). Smart Cities: Ranking of European Medium-Sized Cities. Vienna, Austria: Centre of Regional Science (SRF), Vienna University of Technology.	<i>A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens.</i>
Rios, P. (2008). Creating “the smart city”.	<i>A city that gives inspiration, shares culture, knowledge, and life, a city that motivates its inhabitants to create and flourish in their own lives.</i>
Caragliu, A., Bo, C.D., & Nijkamp, P. (2009). Smart cities in Europe. 3rd Central European Conference in Regional Science (pp. 45-60).	<i>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.</i>
Washburn, D. et al. (2010). Helping CIOs Understand “Smart City” Initiatives: Defining the Smart City, Its Drivers, and the Role of the CIO. Cambridge, MA: Forrester Research, Inc.	<i>The use of Smart Computing technologies to make the critical infrastructure components and services of a city – which include city administration, education, healthcare, public safety, real estate, transportation, and utilities – more intelligent, more interconnected, and efficient.</i>
Harrison, C. et al. (2010). Foundations for Smarter Cities. IBM Journal of Research and Development, 54(4).	<i>An instrumented, interconnected, and intelligent city. Instrumentation enables the capture and integration of live-world data through the use of various devices and sensors. Interconnected means the integration of those data into an enterprise computing platform and the communication of such information among the various city services. Intelligent refers to the inclusion of complex analytics, modeling, optimization and visualization in the operational business processes to make better operational decisions.</i>
González, J.A., & Rossi, A. (2011). New trends for smart cities. Competitiveness and Innovation Framework Programme.	<i>A public administration or authorities that delivers (or aims to) a set of new generation services and infrastructure, based on information and communication technologies.</i>
Zhao, J. (2011). Towards sustainable cities in China: analysis and assessment of some Chinese cities in 2008. Berlin: Springer.	<i>Improving the quality of life in a city, including ecological, cultural, political, institutional, social, and economic components without leaving a burden on future generations.</i>
Lazaroiu, G.C. (2012). Definition methodology for the smart cities model. Energy, 20(1), 326-335.	<i>The smart city represents the future challenge, a city model where the technology is in service to the person and to his economic and social life quality improvement.</i>
Schaffers, H., Komninos, N., Tsarchopoulos, P., Pallot, M., Trousse, B., Posio, E., Carter, D. (2012). Landscape and Roadmap of Future Internet and Smart Cities.	<i>Smart city is referred as the safe, secure environmentally green, and efficient urban Centre of the future with advanced infrastructures such as sensors, electronics, and networks to stimulate sustainable economic growth and a high quality of life.</i>

Cont. table 1.

Dameri, R.P. (2013). Searching for smart city definition: A comprehensive proposal. <i>International Journal of Computers & Technology</i> , 11(5), 2544–2551.	<i>A smart city is a well-defined geographical area, in which high technologies such as ICT, logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well-being, inclusion and participation, environmental quality, intelligent development; it is governed by a well-defined pool of subjects, able to state the rules and policy for the city government and development.</i>
Manville, C. et al. (2014). Mapping smart cities in the UE, European Parliament. Directorate-General for Internal Policies. Policy Department: Economic and Scientific Policy A.	<i>A Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership.</i>
Piro, G., Cianci, I., Grieco, L.A., Boggia, G., & Camarda, P. (2014). Information centric services in smart cities. <i>Journal of Systems and Software</i> , 88(1), 169-188	<i>A smart city is intended as an urban environment which, supported by pervasive ICT systems, is able to offer advanced and innovative services to citizens in order to improve the overall quality of their life.</i>
Prado, A.L., Da Costa, E.M., Thiago, Z., Tan, Y. (2016). Smartness that matters: towards a comprehensive and human-centred characterization of smart cities, <i>Journal of Open Innovation: Technology, Market, and Complexity</i> , ISSN 2199-8531, Springer, Heidelberg, Vol. 2, Iss. 8.	<i>Smart city is a community that systematically promotes the overall wellbeing for all of its members, and flexible enough to proactively and sustainably become an increasingly better place to live, work and play.</i>
Bibri, J. (2019). On the sustainability of smart and smarter cities in the era of big data: an interdisciplinary and transdisciplinary literature review. <i>Big Data</i> , 6(25), 2-64.	<i>A smart city can [...] mean a technologically and data-analytically advanced city that is able to monitor and understand its environment and citizens and explore and analyze various forms of data to generate useful knowledge in the form of applied intelligence that can immediately be used to solve different problems, or to make changes to improve the quality of life and the health of the city.</i>
Toli, A.M., Murtagh, N. (2020). The concept of sustainability in smart city definitions. <i>Front. Built Environ.</i> , 6, p. 77.	<i>Smart city is a concept of urban transformation that should aim to achieve a more environmentally sustainable city with a higher quality of life, that offers opportunities for economic growth for all of its citizens, but with respect to the particularities of each locality and its existing inhabitants. This transformation is currently enabled by various types of technologies that are embedded into the city's infrastructure system.</i>

Many scientists perceive the Smart City as a system or ecosystem created in order to implement innovation and enable the transfer of knowledge. These ecosystems integrate technological and social aspects in the pursuit of the so-called green growth concept, which searches for the optimal solutions to environmental problems (Zygiaris, 2013). From this perspective, cities are being perceived as a set of urban spaces and resorts that provide safety for the natural environment and enhance the potential development of all residents. Researchers emphasize the important factor of collaboration and integration of city authorities with the citizens by means of artificial intelligence and other modern technologies. As a result of this integration, Smart Cities can perform four unique functions (Komninos, 2006) – create collective strategic intelligence (pieces of information which are important to the city and its residents is processed and used by entire local communities), transfer technologies through digital platforms, create innovation-friendly environments through the cooperation of social

groups and city authorities, promote local communities and tourist attractions by using all sorts of IT hardware and software.

Scholars are also trying to describe the Smart City by using various models and frameworks. One of the most popular models of the Smart City concept has been proposed by researchers of the Vienna University of Technology, which has been the foundation of many other Smart City models (Giffinger, 2007). This model consists of 6 dimensions – smart economy, smart governance, smart living, smart environment, smart people, smart mobility. All of these dimensions are interlinked and can be gradually developed by the actions of informed, independent and empowered residents of a Smart City (Giffinger, 2007). Researchers from India have come up with the SMELTS framework (Sujata et al., 2016), which indicate that the core of Smart City consists of three layers – technology, economy and law. On the other hand, elements of sustainable development, management and social activity were considered as complementary aspects. Scientists at University of Cambridge point out that the number of Smart City models and frameworks which describe the phenomenon are constantly increasing and are being updated on a regular basis (Heaton, & Parlikad, 2019). Thereby, in the paper published in 2019, they present a unique solution, the so-called Smart Asset Alignment to Citizen Requirements Framework, in which they demonstrate important correlations between the requirements of Smart Citizens, the dimensions of Smart City and the available infrastructure of the city.

Summarizing the above discussion, we can consider Smart City as *a concept which consists in developing a particular city towards optimal use of resources (tangible, environmental, knowledge capital and social capital) by the means of modern ICT technologies and smart sustainability, which can deliver a wide range of benefits to residents, city authorities and local businesses, as well as increase the overall quality of life of local communities in a particular agglomeration*. Smart City integrates the physical realm of the city with its virtual dimensions, which encourages the creation of local networks and strengthens the processes of optimal resource utilization.

3. Dimensions and Attributes of Smart Cities – An Attempt of Synthesis

Implementing and launching the development of a Smart City is an overwhelming endeavor in case of smaller or medium-sized cities that may face various impediments, especially associated with lack of resources. In order to successfully implement all the attributes and domains of the Smart City concept, such as *smart governance*, *smart energy* or *smart safety*, developing cities have to meet a number of key success factors for the implementation of this modern concept. The key success factors for launching a Smart City and transforming a city into a smart metropolis include the following (Chourabii, 2012):

- proper city affairs management and organization,
- access to technology and the ability of using its potential,
- skillful resource management,
- properly selected operation and development policies,
- satisfactory communication with city residents and local communities,
- positive economic factors,
- current state of infrastructure and its potential for further expansion,
- natural environment and ability to manage natural resources.

Executing a Smart City development project is extremely difficult and there are scientific studies that indicate high requirements in the area of infrastructure and currently used technologies (Su et al., 2011). The entire endeavor of launching and developing a Smart City within a particular town or city should be implemented gradually throughout a project programme. The launch of the entire programme should consist in preparing a special public platform. This platform should primarily be based on special technical infrastructure (hardware and software, including all sorts of ICT devices), systems that collect data and enable cloud computing, and an advanced sensor network (Internet of Things). Moreover, other papers point out the need for bilateral cooperation – technologies and infrastructure alone are not enough to successfully develop the concept of a Smart City. Such endeavor also requires the support from the residents and local communities who must be aware of the Smart City potential as it may affect their daily living (Bouzgeuenda et al., 2019).

There are many research results and academic papers which analyze the unique characteristics and attributes (also known as domains or dimensions) of a Smart City concept. However, despite some cosmetic differences, the substantive content of commonly available studies and articles in this field is almost identical, complementary and reflects the same context. This paper attempts to list all the currently known domains of Smart City. Therefore, the dimensions, also known as domains of Smart City, include the following items (Hollands et al., 2008; Caragliu et al., 2011; Czupich et al., 2016; Camero, & Alba, 2019):

- **Smart Transportation** – includes a range of smart city practices or applications, such as integrated electronic timetables or advanced e-ticketing systems.
- **Smart Environment & Green Zones** – is usually related to the monitoring of urban environmental conditions through sensors and other measuring devices. This dimension is also associated with the creation of *green belts* and *green spaces*, that is, areas filled with natural vegetation accessible to residents (Sanchez-Corcuera, 2019).
- **Smart Energy** – mainly refers to smart management of electricity usage and monitoring of electricity consumption. Smart street lights or dynamic ambient lighting can also belong to this dimension.
- **Smart Water** – is related to optimal management of water resources in urban areas.

- **Smart Buildings & Public Spaces** – may include the above items (Smart Water as well as Smart Energy) in combination with intelligent buildings that monitor their current status according to a set of parameters (consumption, states, lighting levels, etc.). This dimension also applies to publicly accessible co-working offices and urban spaces. In other words, this dimension represents all accessible places or facilities that offer a collection of different technologies and services to city residents.
- **Smart Safety** – refers to surveillance systems and devices (especially cameras) that monitor people and traffic throughout the city in order to increase safety measures.
- **Smart Healthcare** – sometimes also referred to as e-Health, this dimension covers the digitization of health services, such as online diagnostics (e-services and by-phone treatments), but also to more efficient management of dispersed healthcare systems.
- **Smart Governance** – also known as *e-government*, refers to the digitization of traditional, paper-based official matters and city hall services.
- **Smart Economy & Entrepreneurship** – these include *e-business* and *e-commerce* activities. These domains usually consist of various types of ICT-enabled systems and platforms to support local business activity of minor or medium business entities.
- **Smart Living & Smart People** – this dimension includes the integration of local communities, the exchange of knowledge among city inhabitants, full-scale support of personal development of city residents (for example, expanding IT competences), and a more conscious lifestyle, that is, striving for sustainable development.
- **Smart Infrastructure & Technologies** – this dimension is often mentioned in the definitions of Smart City and consists in equipping cities with modern ICT infrastructure (such as Wi-Fi, LTE, 5G and even newer or better technologies).
- **Smart Logistics** – consists in optimizing and adapting the supply chains among city activities depending on the increasing demand for certain goods and services.
- **Smart Education** – is associated with remote education and various training courses or profession exams which are being conducted by special institutes. Also, it refers to the better support of elementary schools, high schools or universities.
- **Smart Stakeholders** – it is quite surprising that this important dimension, which connects important representatives of all research institutions, city offices and the business zone, is often completely missing or is being omitted in the models available in scientific papers and literature. The literature emphasizes the existence of strong links between Smart City and the triple helix model of innovation (Lombardi et al., 2012). In addition, some researchers pointed out that stakeholders can often help in determining what a Smart City actually is or rather it should be in a particular urban area (Praharaj, & Han, 2019).
- **Other types of unique domains affiliated with Smart City.** These can be various types of new technologies or aspects that emerge as the city continues to develop.

In order to provide a clearer overview of all Smart City dimensions included in the list above, we have decided to present them in a synthetic visual form in Figure 1. Initially, we have made an attempt to assign individual dimensions to four main categories – governance, technology (and infrastructure), environmental protection and social aspects. However, it turns out that these categories are to some extent complementary from the perspective of the Smart City concept itself and can mutually supplement each other in the case of a particular dimension. In other words, proper classification and taxonomy of the dimensions and assigning them to the key elements of the Smart City concept (by which we mean people, technology, management, environment) is a difficult task that requires further scientific verification.

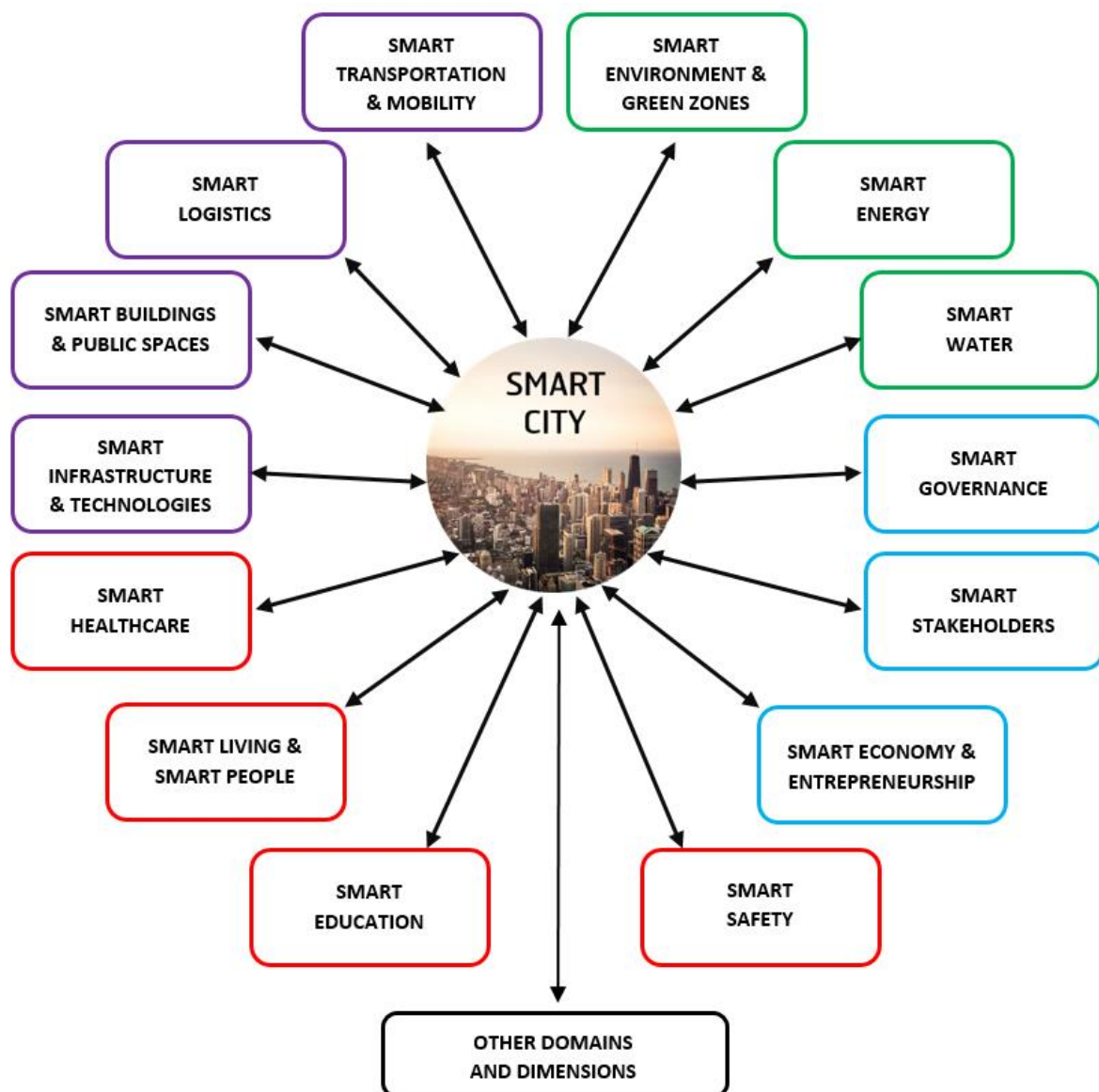


Figure 1. Dimensions and main domains of a Smart City – synthetic approach. Source: own work.

4. Examples of advanced ICT solutions used in Smart Cities – Discussion

The following examples of the application of Smart City technologies illustrate how the cooperation of local communities, companies and city authorities can improve the general quality of life of all inhabitants of a developing city. In addition, some of the questions in the research questionnaire presented in this paper were developed on the basis of the mentioned examples.

The information extracted from the Big Data processes certainly enriches the knowledge of city halls about the functioning of a city and offers many new opportunities associated with social interaction. Also, Big Data may support decision-making in various areas of city management. A great example is the application of a system that processes huge data volumes of public rail transport in London (Batty, 2013), where data mining led to the discovery of a gap – it turned out that a large percentage of public transport users do not swipe their magnetic travel cards before boarding trains or subways. The number of people with public transport cards deviated from the number of cards used by as much as 15%. This is a result of the enormous passenger overloading in the public transport system caused by a very high number of travelers. The researchers also highlight the fact that the Big Data phenomenon and gathering basic data may be not enough – more advanced systems for data analysis and processing are needed, as well as appropriate data sources which can be processed further. The latter could, for example, improve public transport services in certain districts or provide additional transportation connections during rush hours on the basis of selected information (or events, which could indicate that there is a need for additional bus routes). Interesting applications of Big Data within Smart City were presented in the 2016' case study analysis (Hashem et al., 2016). The cited paper indicates that Stockholm has introduced an autonomous system of small vehicles to collect waste in urban areas. In Helsinki, huge amounts of data were made available in the form of databases that residents and local businesses could use for their own purposes in order to improve services or public living spaces. Copenhagen has implemented innovative transportation solutions, waste management, water management and optimized the use of alternative energy sources. All that was available due to the implementation of the Big Data approach.

The Internet of Things (IoT) consists of interconnected and linked sensors, indicators, and devices that perform a variety of specialized measurements or identify certain phenomena and then transmit that data to other systems and other Smart City assets. In terms of IoT, Smart City infrastructure usually includes (Gaur et al., 2015): 3G/4G/5G, LTE, Wi-Fi, WiMAX (interoperability of microwave access), cable TV and satellite communication. The main goal is to connect all kinds of devices (sensors, devices, and electronic objects) that can help in improving the comfort and safety of citizens' lives. A good example can be the new networking solutions which provide faster mobile network technologies, as well as services in virtual cloud

environments that use dozens of public sensors. For example, by monitoring the GPS signal of a particular resident's (or tourist's) phone the integrated system could automatically recommend interesting points of interests or launch a traveler's guide with local sightseeing attractions. All that could be available by using an app released for the most popular Android/iOS operating systems. In case of city authorities, the advantage lies in collecting real-time data about the city and processing it in the cloud in order to obtain important and valuable information. For example, city authorities may decide to use advanced sensors which monitor and manage power consumption in the city depending on the time of day and weather conditions and automatically adjust power consumption to establish the optimal operating conditions. In addition, systems equipped with IoT sensors can be interlinked with healthcare services. In case of the latter the so-called intelligent intersections can identify an accident or any sort of unfortunate events among city area and summon appropriate emergency services to the accident's site (Toh et al., 2019). Another example of IoT application in Smart City can be the integration of the entire local healthcare system with mobile phones and health applications of the residents (Cook et al., 2019). Also, the information containing statistical data about medical conditions and GPS location sensors will prevent potential shortages of drugs in pharmacies located in particular neighborhoods of the city.

Advanced IoT systems can also be used for citywide security monitoring in order to extend the camera modules of regular monitoring of local landmarks (or neighborhoods) with fire detection software and other variety of safety-monitoring devices. It is also worth to mention that IoT technologies often take part in such domains as smart energy management, smart waste management, parking assistance and traffic control systems (Gaur et al., 2015). These are just a few of the many examples of IoT applications in a Smart City. All of the IoT application examples cited here are already being used in practice in such cities as Padova in Italy or Vienna in Austria.

Artificial Intelligence (AI) is usually associated with intelligent, autonomous drones that deliver packages, driverless cars, or even intelligent buildings that take care of the maintenance on their own (e.g. by using an advanced system of autonomous vacuum cleaners that clean floor space or autonomous drones to clean windows). However, these are technologies and solutions which are still being tested and implemented in the form of prototypes. Despite that, AI algorithms are significantly speeding up data processing and are complementary to the autonomous decision-making systems within the management services and economic activities of a Smart City (Allam, & Dhunny, 2019). In the case of large data sets collected by IoT sensors, the use of artificial intelligence is actually required (Patel, & Doshi, 2019). There are many Smart City domains in which AI plays a supporting or key role, namely: education, environment, energy management, healthcare, development policy, financial services and financial management (city finance), mobility, sustainable development, IoT services and technologies, Big Data processing and cloud computing. A good example of the practical application of AI can be the already mentioned intelligent intersections. These junction-

controlling systems change the frequency of traffic light shifts depending on traffic intensity and can detect dangerous vehicle collisions. The latter system makes it possible to call medical services as soon as the incident occurs, which can increase the chances of survival of those who got injured. Another interesting example can be the so-called anti-smog zone. If IoT sensors detect high air pollution in the city center, a number of streets can become a temporary car-restricted areas in order to reduce the level of air pollution. Limited traffic zones can be controlled by the AI system which, based on the collected and analyzed data about the current status of the air quality, will change traffic lights or display important notification on the LED street signs.

All examples and cases which were mentioned above should be treated as a general overview of most popular solutions and technologies that improve the quality of life within a Smart City.

5. Conceptual Research Framework – Methodology & Research Tools

5.1. Instructions and recommended research method

This type of research can be conducted in a city that exhibits potential or willingness towards implementing the Smart City concept. The research sample should be determined according to the number of residents of the examined city. We suggest to carry out the questionnaire in anonymous form and to address it only to the residents of one particular city. Each questionnaire respondent should be at least 15 years old (and should have been living in the investigated city for at least 3 years). The research tool in a form of a questionnaire includes both quantitative and qualitative questions. We have analyzed and verified other tools which were used in similar studies. This allowed us to polish our own approach and determine a set of unique questions (check subchapter 5.2 and 5.3 of this article). The quantitative questions are mainly related to the study of residents' awareness of the Smart City concept, as well as their views on this phenomenon. The qualitative part of the research mainly focuses on the evaluation and identification of the needs of local communities that could be fulfilled by the implementation of the Smart City concept in a selected urban area.

5.2. Overview of available tools for measuring and governing Smart City capabilities

Since the mid-90s, large cities have already begun to use comprehensive measurement systems in order to check the status of local urban processes on a massive scale. Therefore, the monitoring of various environmental and social parameters within particular agglomerations has been carried out on a regular basis for many years. Usually, such activities are being conducted by the use of analytical IT systems which are combined with information

boards, local enterprises, sensors placed around the city and any other devices or systems that may be related to public services. This has ignited the need of new measurement tools that would allow local authorities to measure the level of intelligence of a specific city. These tools include various models and approaches, namely:

- Smart City Model developed by researchers at Vienna University of Technology (Giffinger et al., 2007) – has a number of different indicators and factors (90 indicators contained in 27 factors) that allow to assess the level of intelligence of the studied city.
- Smart City performance measurement tool developed by Kominos N. & Sefertzi E. (2009), consisting of 40 indicators in four categories: education and skills of the population, institutions influencing knowledge and innovation, digital infrastructure and e-services, innovation performance.
- Lombardi's Quadruple Helix model (2012) – based on the verification of 60 indicators in five categories: economy, quality of life, environment, people and management.
- Priano & Fajardo's (2014) model of independent evaluation of n-dimensions of a Smart City – consists in individual measurement of the development level of a particular area or attribute without associating it with other parameters.
- Smart City intelligence and resource measurement methodology based on Digital-Twin model developed by Petrova-Antonova and Ilyeva (2019) – it integrates the virtual layer with the tangible layer of the city through appropriate systems and indicators.
- Conceptual multidimensional model for measuring Smart City potential (Nasrawi et al., 2015).
- The Smart City Maturity (SCM) Model (Caird, & Hallett, 2019) – helps to determine the level of maturity of a city and its development perspectives in relation to other cities by performing benchmarking analyses.

The social implications of a Smart City are being constantly discussed in the literature (Patel, & Doshi, 2019). The main reason which led us to the development of this research tool was the very poor performance of Polish cities in terms of the entire Smart City concept. According to various studies and reports, Polish cities are only starting to take an interest in the Smart City concept and are at an early stage of development of Smart City dimensions (Pichlak, 2018). One of the main problems of Polish cities is their continuous focus on current problems such as road infrastructure, lack of interest in newer technologies, lack of funds for research and development activities and, first and foremost, a constantly growing debt level caused by the number of investments which must be carried out instantly. The most developed cities in terms of the Smart City concept in Poland include Warsaw, Cracow, Wroclaw, Poznan and Gdansk. Therefore, there is a significant research potential in this particular area.

5.3. Overview of tools and frameworks for measuring residents' satisfaction and awareness towards Smart City

Scientific literature offers a wide range of tools and frameworks to verify the Smart City effectiveness and efficiency of Smart City dimensions. Both of these aspects mainly consists in identifying residents' opinions about Smart City or examining the performance of various resources and services that are being used in a Smart City. Such tools can be divided into pre-Smart City frameworks and post-Smart City frameworks. Pre-Smart City research relates to emerging Smart Cities or covers a range of activities and events prior to their potential creation such as papers which conduct studies in the area of advantages of Smart City construction and its impact on people's lives based on big data and rational planning theory (Xiao, Xie, 2021). Other articles which can be assigned to this type of research often highlight the main requirements and factors of creating a Smart City in particular areas (Jonek-Kowalska, Wolniak, 2021). The post-Smart City research involves advanced Smart Cities or cities that are currently in-development in order to achieve the Smart status. These type of frameworks strive to measure social capital indicators in order to determine the level of neighborhood management (Nanako, Washizu) and key performance indicators of advanced Smart City services which are being used by residents (Airaksinen et al., 2017). Therefore, it should be pointed out that the type of research carried out and the types of research tools are determined by such criteria as the level of development of a particular city towards the desired Smart City vision (e.g. ethical framework for Smart Cities, that focuses on measuring the ethical and non-ethical issues in big data analytics applications in Smart Cities and public transportation systems – Chang, 2021), the object and the subject of the research, and the period of time in which the research was conducted.

However, due to the scope of this paper we have decided to focus only on those frameworks which contributed to measuring the awareness and satisfaction of Smart City residents or local communities that may become a part of a Smart City in the nearest future. The most recent research frameworks and most popular research tools, which were used to measure the residents opinion about Smart City in the context of awareness have been presented in table 2.

Table 2.

Analysis of studies and research results relating to the issue of citizen or resident awareness towards Smart City concept

Authors & year of the study	Research's objective	Key findings and conclusions
Kopackova H., Komarkova J. (2020)	Participatory technologies in smart cities: What citizens want and how to ask them.	This study reveals that younger groups of citizens are willing to be aware of city issues and smart city events only if they get the proper mobile communication tools, that is, software solutions developed towards better participation between particular groups of citizens and city authorities.

Cont. table 2.

Macke, J. & Casagrande, R. & Sarate, J. & Silva, K. Kelin (2018)	Smart City and Quality of Life: citizens' perception in a Brazilian case study	The research analysed the city of Curitiba, in Southern Brazil, claimed to be one of the Smartest Cities in the world. The results revealed that most citizens are not only satisfied of the offered Smart City services but also not aware of all available services.
Tingting Ji, Jieh-Haur Chen, Hsi-Hsien Wei, Yu-Ching Su (2021)	Investigation of citizens' preferences and perceptions about smart-city services in Taiwan	Citizens had to rate 35 Smart City services of seven dimensions classified in two domains in the context of the usefulness of all mentioned services in the realization of human needs. The results show that most of the respondents clearly perceived Smart City services as both important and useful to their existence, relatedness, and growth needs.
Kamnuansilpa, P. et al. (2020)	Citizen Awareness of the Smart City: A Study of Khon Kaen, Thailand.	Around 50% of respondents were aware of the Smart City concept and over 85% were not aware that city authorities may be planning to implement the concept in a particular urban area.
Min Jee Nikki Han, Mi Jeong Kim (2021)	A critical review of the smart city in relation to citizen adoption towards sustainable smart living	There is a lack of research from a human-centric viewpoint (citizen adoption) and it's worth to explore the citizens perception in that matter.
McKinsey Global Institute (MGI), June 2018, McKinsey&Company	Smart City Report: Smart Cities: Digital Solutions For A More Livable Future	MGI has conducted an international research on awareness, usage and satisfaction levels among the residents of 50 Smart Cities worldwide (including developing Smart Cities). It turns out that young population has the highest awareness of Smart City services and even demands many digital utilities mainly as a result of increasing popularity of modern and seamless technologies.
Rasic M., Milenkovic M., Vojkovic G. (2018)	Smart-city — Awareness amongst Croatian citizens	The research questionnaire was completed by a total of 673 respondents. This study revealed that 69% of respondents were aware of the Smart City concept and Smart City services, but 88% of them stated that they don't live in a Smart City yet and only 19.3% of them knew what their local government is doing regarding smart-city implementation projects.
Cagánová, D., Stareček, A., Hornáková, N. et al. (2019)	The Analysis of the Slovak Citizens' Awareness about the Smart City Concept	Key findings revealed that 65% of respondents had no idea what a Smart City actually is. The researchers suggest the best ways of solving that issue as informed and participating citizens can make Smart City implementation more effective or efficient.
Molinillo S., et al. (2019)	Smart city communication via social media: Analysing residents' and visitors' engagement	This research conducted in major cities of Spain indicates that Smart City fails in terms of social media aspects and the awareness of Smart City social media content is very low.

5.4. Detailed description of the research tool – a questionnaire

This subsection includes a series of quantitative and qualitative questions used in the research tool that will identify the respondents' level of knowledge about Smart City, as well as identify the key needs of residents who live in a developing Smart City. Table 3 provides the key quantitative research survey questions.

Table 3.*Questions regarding residents' awareness of the Smart City concept*

Have you ever heard of such a term as Smart City? (Please underline or bold the selected answer)			
Yes, I know this term	Probably/Maybe I have heard it somewhere	It's hard to say/ I don't know	No, I have never heard it before
What is a Smart City in your opinion and what does this term actually mean? (This is a single-choice question. Please fill in the 'X' symbol in the appropriate box.)			Answer (single-choice)
It is a concept and idea of city development which uses modern ICT technologies in order to provide benefits to local entrepreneurs			
It is a concept and idea of city development which uses modern ICT technologies, provides benefits to citizens, and supports city authorities and local entrepreneurs			
It's a complex tool designed to build new cities that can be used by city authorities and officials			
Smart City consists in possessing the knowledge on how to live in a modern city and it is a new way and style of living of the 21st century			
It is a modern technology used for managing the city, which can be purchased from an IT company - it is mainly dedicated to the city authorities			
It is a new type of product made by innovative companies			
Which of the following items can be considered as key benefits of a Smart City? (Please select the proper answer YES or NO.)			Answer
Lower prices in stores located within the city			YES NO
Increased wages for residents working at city businesses			YES NO
Free public transport services			YES NO
Transparency of information and access to city databases for citizens (e.g., providing public data on transportation, the number of businesses operating, or the current state of the environment, etc.)			YES NO
Active protection of the local natural environment and reduction of pollution (e.g. introduction of green zones, electric cabs, etc.)			YES NO
Better management of urban space (e.g. creation of new leisure and tourist zones, etc.)			YES NO
Modernization and optimization of transportation services (e.g. introduction of electric buses – less noise and less car fumes, modern phone applications monitoring the condition of public transport lines)			YES NO
Improving the quality of life of residents by enabling e-services (e.g. launching such services as e-doctor, remote education, etc.)			YES NO
Increased level of security in the city (e.g. use of artificial intelligence in city monitoring)			YES NO
Improved communication between city authorities and citizens (e.g. launching an Internet platform and IT systems enabling the resident to evaluate various services of the city and to make decisions on its further development)			YES NO
Support in the area of energy (e.g. installing generators of renewable energy sources, creating local and complementary energy networks)			YES NO
E-Office and E-Government – facilitation of official matters and services available to the city residents (e.g. better support in conducting business activity within the city, simpler procedures in dealing with official matters – virtual online service)			YES NO
Easier access to high-speed Internet connection and modern technologies (e.g. better access to fiber optic infrastructure and network devices)			YES NO
Other benefits:.....			YES NO

Cont. table 3.

Have you ever used the services of another, fully-developed or partially established, Smart City?	
YES	NO
1. Name of the city:	
2. Description of the Smart City service:	
3. Please indicate your level of satisfaction of the service in a scale from 1 (low satisfaction) to 5 (high satisfaction):	
Please specify three words by which you could define the concept of a Smart City (or which you associate with Smart City - open question)	
.....	
Please describe what sort of domains or dimensions should be included in a Smart City concept. In other words, what sort of activities should be involved within a Smart City? (open question)	
.....	
.....	

Source: own work on the basis of various approaches indicated in Mohanty S. (2016). *Everything You Wanted to Know About Smart Cities. IEEE Consumer Electronics Magazine*. 5 and Hamilton E. (2016) *The Benefits and Risks of Policymakers' Use of Smart City Technology*. Mercantus Center, George Mason University, Arlington, Virginia.

Key qualitative research questions of the questionnaire were listed in Table 4. As can be seen in the Table 3, each question should be answered in the Liker scale, that is, with a score rating in the scale of 1 to 5. This will allow respondents to specify their level of agreement or disagreement with suggested potential of specific attributes of Smart City.

Table 4.

Questions regarding the identification of key resident needs that can be met by using the Smart City concept

Smart City Attribute (also known as Smart City dimension or domain)	Technologies and examples of their application in a particular area - please try to assess to what extent a certain technology could be applied in your city (evaluation of the potential of each attribute/dimension of Smart City)	Score & Ratings (please use the Likert scale of 1 to 5, where 5 is the most needed solution and 3 is a neutral rating)				
		1	2	3	4	5
Smart Buildings & Public Spaces	Intelligent buildings with automatic heating, air conditioning and ventilation systems (or other systems that adapt to the environment)					
Smart Healthcare	GPS monitoring system for the elderly					
Smart Healthcare	Monitoring of vital signs integrated with the resident's healthcare office/medical clinic					
Smart Healthcare & Smart Logistics	Intelligent drug stock replenishment system in pharmacies, for example, usable in cases of high demand for a particular drug					
Smart Energy	Smart Grid systems and applications – intelligent city lighting depending on the time of day					
Smart Parking	Smart Grid applications – smart parking lots (Google Maps applications can inform residents where to park), intelligent traffic monitoring and traffic intensity management (may reduce traffic intensity or traffic jams at busy intersections)					
Smart Utilities	Measurement of water, gas and energy consumption in real time – module available to residents as well as city authorities					

Cont. table 4.

Smart Logistics	Synchronization of supply with demand for goods, for example, the stock of certain goods may be refilled quickly					
Smart Transportation & Mobility	Electric cars – online vehicle sharing service (accessible via mobile apps)					
Smart Transportation & Mobility	Intelligent intersections and traffic monitoring (imposing restrictions in case of an accident and immediate notification of emergency services provided by the AI system)					
Smart Governance	Access to the city's virtual platform via mobile phones/computers – residents will have an opportunity to establish direct contact with city authorities/offices. Transparent access to statistical data of the city					
Smart Environment	Additional air quality sensors and weather monitoring that alerts residents of hazardous conditions					
Smart People	Possibility to work in virtual environments and take online self-development courses (provided by the city hall or other institutions) – remote expansion of residents' knowledge					
Smart Living	Additional sports & healthy living services, for example, smart bikes and scooters					
Smart Environment	Smart bins, waste containers and additional notification systems which notify about overfilled disposal containers					
Smart Transportation & Mobility	Smart notification system that notifies residents about dangerous events, various unforeseen events or other activities					
Smart Economy	Launching of a local technology transfer platform for smaller entrepreneurs – support from wealthy residents and knowledge exchange among residents					
Smart Economy	Additional support in launching modern technologies or new products by establishing a local crowdfunding or public e-commerce platforms					
Smart Living	Additional tourism and educational services, such as an interactive sightseeing app					
Smart People	Establishment of a greater number of supporting initiatives of various types and initiatives to promote creativity among local communities					
Smart Transportation & Mobility	Increased accessibility to high-speed Internet and public Wi-Fi in many city neighborhoods					
Smart Living & Smart Environment	Access to real-time measurements of noise emissions at selected locations					
Smart Environment	Creation of publicly accessible green zones in the city					
Smart Energy	Advanced energy management – more efficient and cost-effective use of energy based on traffic conditions, weather conditions, and real-time power consumption					
Smart Safety	Additional security systems to monitor and warn of dangerous events/people (crime or accident detection system supported by AI)					
Smart Healthcare	E-Doctor or E-Healthcare services used for faster disease diagnosis and prevention of illnesses					

Cont. table 4.

Smart Safety	Monitoring of disasters and unexpected events such as fires					
Smart Water	Optimal water management, especially in cases of hot weather or in case of sewage flow optimization					
Smart Safety	Advanced network connection encryption systems – greater security of city residents while using the Internet services					
Other attributes and needs suggested by city residents:						
Attribute/Smart City Domain	Description of needs that can be met through the use of Smart City concept and modern technologies - are there any other technologies or facilities that, in your opinion, could be useful?					
	(Please write down your ideas, domains, needs or initiatives in the rows available below)					
.....					
.....					
.....					

Source: own work.

One of the key elements of the questionnaire should be the demographics section in which each respondent has to provide important information about his or her unique characteristics, as we have recommended in Table 5.

Table 5.
Recommended Demographics Section of the research tool

Questionnaire’s Demographics Section	
1. City of residence within the last 3 years:
2. Age group:	Answer:
- 15-20,	
- 21-25,	
- 26-30,	
- 31-35,	
- 36-40,	
- 41-45,	
- 46-50,	
- 51-55,	
- 56-60,	
- 61+	
3. Gender:	Answer:
- Male	
- Female	
4. Education:	Answer:
- Primary Education	
- Secondary Education (Undergraduate)	
- Higher Education (Postgraduate)	
- Trade School or other form of Education	

Cont. table 5.

5. Working experience and status:	Answer:
- Pupil of Secondary School/High School	
- University Student	
- Employee of a Business Entity/Company	
- Entrepreneur/Manager (Large Company, Medium, Small or Micro Company – please underline the company size)	
6. Use of public services:	Answer:
- public transportation,	
- libraries and public institutions,	
- co-working zones,	
- apps that monitor local events and air pollution levels,	
- other services:	

Source: own work.

5.5. Preliminary research results – verification of usefulness of the research tool

In order to verify the reliability and usefulness of the research questionnaire developed in this paper, we have decided to use the preliminary results of the first phase of research on the awareness of residents towards Smart City in the Silesian Voivodeship in Poland. The questionnaire was filled by 103 individuals, of which 60% were residents of Gliwice city and 20% were residents of Zabrze city. The remaining part of the respondents live in various neighboring cities. The first phase of the research was addressed mainly to the younger generation, therefore out of 103 respondents as many as 80% belonged to the age group between 21 and 25 years old. The first part of the study helped to determine the extent of residents' awareness of the Smart City. As many as 80,5% of the respondents indicated the most optimal definition of Smart City, referring to all the benefits of this concept. In addition, 34% of the respondents are familiar with the concept of Smart City and 47.5% of the respondents said that they have heard about the Smart City idea in the past. The open-text questions performed very well, as 92% of respondents identified unique words to describe Smart City and identified domains or services which they thought Smart City should be identified with. The second part of the questionnaire allowed to determine the preferences of residents of the selected territory in terms of Smart City services and domains. We were also able to get feedback from several respondents who said that these types of questions, which contain pre-defined Smart City domains and services, are very reasonable, because many city residents may not have enough knowledge about all the services the Smart City can offer.

6. Conclusion

This research paper proves how complex and complicated the concept of Smart City is. The literature review of Smart City definitions revealed that the main objective of the entire Smart City approach is to improve the quality of life of residents of modern agglomerations and simultaneously support the local entrepreneurship. Integration of the local community sphere, infrastructure and city authorities by applying modern ICT technologies is the foundation of the Smart City concept. This study characterizes all Smart City attributes and offers a synthesis of commonly known domains and dimensions of a Smart City. Identifying all commonly used (or known) dimensions of Smart City is challenging but it proves the multidimensional nature of the concept. Launching a Smart City project in small and medium towns or in large developing cities can be a tremendous challenge in financial and infrastructural terms, but city authorities shouldn't forget about the most important factor - the beneficiaries of such endeavor, that is, city residents. The latter can be considered as the key stakeholders of the Smart City project, who should express their opinion about the progress of the particular development tasks on a regular basis. In other words, city residents should determine whether they are ready for modern technologies, whether they know how they could use them, and above all, whether they understand the potential of modern tools that make it possible to create transparent knowledge-based communities. The presented research tool in the form of a questionnaire can be used in case of empirical studies that aim to identify public awareness of Smart City and to identify social needs within the Smart City concept. The research survey can be modified and expanded with additional questions. The topic of Smart City is constantly evolving and its scope is quite extensive. Therefore, conducting regular studies (from different perspectives) on Smart City seems to be justified and valuable.

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