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Big Data, Artificial Intelligence, and the sustainable development of cities… …in the (post) COVID-19 era

Abstract

Today, more people live in urban than in rural areas. Hence, the main challenges of our time relate to cities and their sustainable development. Due to the collection of Big Data, the development of Artificial Intelligence algorithms, 5G broadband data transmission technology, the Internet of Things, and mutual communication between machines, cities are becoming more and more intelligent. The vision of a future in which millions of devices, cameras, and sensors constantly monitor, analyze, and regulate city life is by no means a distant prospect. Indeed, some of its elements were already introduced to cope with COVID-19 pandemics. The use of technology allows for the improved connectivity of rapidly increasing urban populations, promotes the creation of smarter and safer modes of transportation, and promises better traffic, congestion, energy and water management.

Technology alone is not enough to make a city better – its use must meet the real needs of urban residents. Nor should technology be exclusive, for not everyone has access to the internet or can use it. Ensuring greater social integration and inclusion, i.e., involving all citizens in the benefits of modern technologies, is a big challenge. It is also important to define an ethical framework for devising solutions that use Big Data and Artificial Intelligence to reduce the risk of unauthorized use and increase trust in AI solutions. In the context of the rapid ageing of the EU population, increased access and affordability of services aimed at seniors is of great importance. An important barrier to the development of this type of technology is that of the still high costs and lack of regulation. Low deployment costs (also in the environmental-impact sense) are a key factor for the sustainability of smart city solutions. Such solutions also need to be safe, reliable, scalable, inclusive, and transparent to citizens. The smart city may therefore offer a number of benefits in the management and optimization of traditional public services.

Introduction

Today, more people live in urban than in rural areas. Therefore, the main challenges of our times relate to cities and their sustainable development. Currently urban governance and policy decisions are to a large extent influenced by the technological revolution and the emergence of new concepts and tools: Big Data, the Internet of Things (IoT), machine learning and Artificial Intelligence (AI), algorithms, and cloud computing (Barro et al. 2018, Allam and Dhunny, 2019). The idea of incorporating technology into the day-to-day activities of people living in cities to provide them with better living standards led to the emergence of the smart city. The purpose of this article is to present a short overview of the technology used in the backstage of smart cities, explain the relevant opportunities and challenges of smart cities, and formulate some policy recommendations.

The concept of the **smart city** is very widely used, though it is hard to clearly define. The crucial aspect is the use of Information and Communication Technologies (ICT) that are applied by government and society in order to create better living and working conditions. The participation of citizens, their partnership with urban authorities, and in general the collaboration between all stakeholders is necessary, since ICT is only a tool for achieving the goal of more comfortable living. Other important goals include better allocation of resources, sustainable economic development[1], environment protection, and the improved cost-efficiency of municipal policies. However, without society's involvement these goals are very hard to reach.

Modern cities face a number of problems. Following Winkowska et al. (2019, p. 71) we can list them as follows: urban sprawl, environmental pollution, urban logistics, technical infrastructure, waste management, ageing population, stratification of wealth levels, areas of poverty, and the low level of citizen participation in the management of public affairs. Transformation into a smart city can solve some of these issues and alleviate others. However, some authors describe this approach as techno-optimism (e.g., Inclezan and Pradanos, 2017), since such transformation is complex and costly and may cause other problems, among which the most important seem to be: investment in technology as a goal itself, without relevance to real problems; the focus on huge projects, new infrastructure, and disregard for the improvement of old facilities; and an increase in inequalities and exclusion due to the uneven application of ICT, lack of technical literacy, and the costs of tools, in particular this pertains to the poor and elderly. There are also issues connected with ICT itself, like privacy concerns, algorithmic bias, machine ethics, and "bad" artificial intelligence. While trying to solve the current municipal problems via the holistic implementation of the smart city, we cannot ignore these concerns. Moreover, most cities have only begun striving towards "being smart", although this process has sped up because of COVID-19 pandemics. Nevertheless, most of the problems of "smart cities" are somewhere in the future and there are not so many real cases to refer to. The main current problem is with the availability of data (Ryan and Gregory, 2019) and its efficient use. Some of the failures and challenges are connected with the costs of smart city projects; thus, this issue is also a subject of our analysis. Other important challenges are connected with ethical considerations concerning cities, new technologies, and artificial intelligence and we have to address them while talking about smart cities. Finally, we will discuss the role of governments and regulations and offer some policy recommendations for the European Union and its member states.

[1] According to the United Nations definition, the smart city is a sustainable city. The UN even uses the joint term "smart sustainable city". See International Telecommunication Union (2016).

Technology behind the scene – Big Data, IoT, ML, AI

The term Big Data refers to large datasets containing diverse data, also in unstructured form (e.g., textual data, images, videos). Their scale makes processing and statistical analysis using traditional computers and statistical tools difficult, sometimes even impossible due to the limited size of disk space, operational memory, or the lack of appropriate statistical tools. The added value of analyzing this type of data is the opportunity to discover surprising, previously unknown dependencies that allow you to acquire new, often profitable knowledge. The obvious example of Big Data analysis is the processing of data collected by large Internet players (the famous "gang of four" or GAFA: Google, Amazon, Facebook and Apple, sometimes including in addition Microsoft). The list of pages visited on the Internet, phrases entered in a web browser, social media, or free e-mail service (even those ultimately deleted before sending), time spent on individual pages, clicked links, products bought online, list of friends, and content published on social networks are a mine of knowledge about every internet user. The challenges for large data sets are their storage and efficient processing.

Large amounts of data are used to feed **machine learning** (ML) algorithms, which are used to discover relationships between individuals and then segment them in groups behaving in a similar way or predict their future behavior. For example, based on the history of websites visited by Internet users and information shared on social networks, it is possible to predict their gender, marital status, education, job position, religion, sexual orientation, and various types of preferences and inclinations – e.g., the propensity to change their job or end their current relationship in the near future (Kosiński et al. 2013). One can equally effectively forecast many Internet users' behaviors and anticipate their needs (e.g., shopping) – even those not yet realized. Companies collecting this type of data often know more about Internet users than their loved ones. Modern machine learning algorithms are used to support and to a large extent automate decisions. One of the most successful machine learning algorithms is that of (artificial) **neural networks** that represent an attempt to mimic the principles of the human brain. A neural network consists of simple processing elements (neurons) grouped in layers and interconnected via weights. **Deep learning** is another modern term which generally means using neural networks with many layers of neurons. All of the above mentioned elements are crucial components of **artificial intelligence** (**AI**). There is no single and commonly accepted definition for what AI is. In general it refers to the effort to automate intellectual tasks normally performed by humans (The English Oxford Living Dictionary). In other words, it is the analysis of data to model some selected aspect of the world and use a predictive algorithm to make inferences (understand) and anticipate (predict) possible future events – U.K. Government (2016), Miailhe and Hodes (2017). AI systems have the ability to perform operations analogous to learning from examples and making decisions. AI has been known since the early 1950s, but its applicability was limited. It exploded with technological progress, the increasing computing power of computers, and the capacity of data collected.

Using Big Data analytics and machine learning/artificial intelligence makes the life of Internet users easier. The data are collected not only online, but also by using GPS receivers located in smartphones, smartwatches, and other devices measuring the daily activity of their users. These devices, due to the fact that they are usually carried by owners, are known as "wearables". Never before has data on various human activities been generated at such a high pace. Technological progress means a further increase in the scale of big data. We are already talking about smart apartments, home appliances (e.g., fridges), and even smart

clothes equipped with sensors collecting various information and communicating with other devices without the participation of their owner. Such communication directly between devices is called the **Internet of Things** (IoT). IoT is a future vision in which the objects used in everyday life equipped with computing, storage, and sensing capabilities will be able to communicate with one another and with human users, thereby becoming an integral part of the Internet (Zanella et al., 2014).

The increasing amount of Big Data has a de facto spatial nature – containing geolocation information. Hence the emergence of the concept of **spatial big data** (Eldawy and Mokbel, 2016). This is the nature of data on the return route from work or a walk or the location of the most visited stores or service outlets (card payments) or the current location of the car. It is this type of data which allows us to identify people who potentially had contacts with the victims of the COVID-19 pandemics. The concept of big data also includes information collected by satellites, including climate and weather data. About 45% of the satellites currently in orbit are used for commercial purposes (UCS, 2019). In cities, the data collected by satellites can be used to analyze vehicle traffic volumes, to create a numerical model of land cover and three-dimensional models of cities that are then used for spatial planning, and to analyze the spread of noise and pollution. Another application of raster data from satellite imagery is that of designing the routes of road and rail lines, pipelines, recording high voltage lines and detecting their collision with crowns of trees, or creating a numerical model of land cover for forest areas, which is then used for planning roads, drainage systems, etc.

Applications of Artificial Intelligence and machine learning technologies in cities will enable the collection of near real-time data and provide a deeper understanding of how cities function and change in adapting and responding to various conditions. Local governments will be able to ensure better provision of urban services (Allam and Dhunny, 2019). The next section describes selected benefits and solutions.

Opportunities (benefits) and solutions

One of the most common ways of using IoT and AI to make urban life better is **smart traffic management.** Installing sensors on the road surface and closed-circuit cameras allows cities to monitor the flow of traffic in real time and notify users about congestion, traffic signal malfunctions, and alternative routes. This solution might be linked with the additional priorities for public transport (special road lanes for public transport buses, green-wave for trams, etc.). That helps city inhabitants get from one point to another as efficiently and safely as possible

Another AI/IoT application related to traffic is **smart parking**. Finding a parking space in a city center might be a real challenge, especially during rush hour on a business day. Road surface sensors installed in the ground on parking spots allow easy determination of whether the spot is free or occupied. Based on that information a real-time map of city parking spots can be created and updated in real time. This not only allows for the efficient use of the existing parking spots, but also reduces the time drivers have to spend looking for an empty space. Therefore smart parking also helps to reduce congestion and pollution. In addition, this solution can be used to automatically verify parking permits in slots reserved for disabled or residents, offering citizens better service (Lee et al 2016).

Every street in the city needs lighting, and this is very costly – powering streetlights accounts for 30%–50% of a typical city's energy bill. Energy consumption and costs can be reduced with **smart lighting**. With this solution city lamps can optimize the intensity of light according to the time of the day, weather conditions, and the presence of pedestrians, cyclists, or cars. Sending information between the neighboring lamps

allows the creation of a safe circle of light around pedestrians or cyclists and reduces light pollution elsewhere. Therefore the level of lighting depends on time and street specifics – this solution is also called motion sensitive street lighting. Cities can thus adroitly balance energy usage and citizen comfort. In addition, well designed and controlled streetlights help cameras capture images of higher quality. This in turn improves the safety perception of citizens and keeps criminals away.

This is strongly related with another example of using AI and IoT in smart cities – namely, **smart policing**. Apart from improving the delivery of services of uncontroversial value as mentioned above, technology may also enhance the power of a more contested service: policing (Joh, 2019). Networks of cameras and sensors help to prevent crime from occurring. They allow for efficient identification (facial-recognition technology) of people behaving suspiciously or committing a crime, monitor crowd density, the cleanliness of public areas, and also track the exact movement of all registered vehicles. Place-based predictive policing software helps to forecast where crime might occur in the future (Fry,2018). Social-network analysis predicts which persons might be future victims or perpetrators of gun violence.

The same road, parking, and lamp sensors may be used to monitor the **quality of air** and the **level of noise** (a form of acoustic pollution) in crowded areas, parks, or fitness trails, so that people can always find the healthiest path for outdoor activities (Zanella et al 2014). All urban sensors (on the road surface or street lamps) can also serve as **free Wi-Fi network hotspots**.

Another essential city service is the collection of waste and its proper management and disposal – due to the cost of the service and also the problem of storing the garbage. The use of AI solutions can provide a sustainable and **smart waste management** system introducing savings and ecological advantages. Sensors installed on waste containers can detect the level of load and send notifications to dispatch the waste collection trucks as soon as they are about to be filled. In addition, it may allow for the optimization of the collector-truck routes and thereby reduce the cost of waste collection (Nuortio et al, 2006).

In the context of both the pandemics and the rapid ageing of the EU population, increased access and affordability of high quality healthcare is also of great importance. AI technology enables **smart healthcare** – with the use of wearable devices like fitness trackers or fitness bands it allows the automation of medical diagnostics and assistance at the right time in case of life-threatening danger (Cook et al. 2018). Quarantined patients and suspected cases can be monitored in real-time, not only controlling if they maintain their isolation but also allowing for diagnosis of their condition without the need for a direct contact with medical staff and other people. Older people (patients) can be monitored in real-time, and the data collected by such devices can be analyzed by doctors, researchers, and health care professionals – and this leads to more personalized, better diagnosis and solutions. At the same time it offers savings of costs and time for both patients and hospitals. Applying predictive machine learning models on large amounts of collected data can play an important role in the healthcare observation of the population and help in predicting the development of diseases like the COVID-19 or the early detection of other health issues. Apart from monitoring applications, smart city solutions might also be applied to support the activities and participation of older and/or disabled citizens and promote healthy lifestyles – e.g., by providing them with educational initiatives concentrated on walking, diet, and socializing, or investing in smart home technology to allow seniors to be independent even in old age (Rocha et al., 2019a, 2019b).

In general the COVID-19 outbreak had impact on the development of some smart city solutions and may give lessons for future – smart city solutions may defend against future pandemics. One of the most important

results is the acceleration of the digital transformation strategies (Industry 4.0). One could observe acceleration of the development of remote city services and medical consultations (public and private) during the lockdown (Agostino et al. 2020). Using already implemented technologies cities were able for example to check temperature remotely with thermal cameras, use real-time heatmaps to control crowding in public spaces, or enforce the social distancing rules using drones/robots.

The main purpose behind the idea of the smart city is to make life in cities more comfortable, safer and convenient for their inhabitants. This also requires **smart governance,** i.e., the use of data and technology for more efficient, informed, and evidence-based decision making by city authorities and for improved collaboration and communication with citizens, NGOs, businesses, and other stakeholders. However, the smartness of the city also raises several important questions and challenges.

Challenges – a Critical View on Smart Cities and AI

Nowadays everything about a city and in a city is to be smart: a smart economy, smart mobility (with smart parking), smart environment, smart governance providing smart services to smart people living smart lives. With the right resources, using technology we can achieve all those objectives, at least nominally. However, in practice it is not certain that we will achieve the stated objective, i.e., comfortable living for all the inhabitants. Potentially there are some negative consequences of such changes and thus numerous problems will appear as cities advance towards this goal. In a way, we can become too successful, creating what Munoz and Naqvi (2017, p. 1) called an "Elysium city", whose "… agents will be technologists, technocrats, intelligent machines, and wealthy capitalists…" For all others there will either be no place in such a city, or they will have to live in some kind of modern slums on the outskirts of smart cities. Thus, for a smart city to increase the quality of living for everybody, or at least for most of its inhabitants, and to achieve inclusivity, we have to apply participatory models, where citizens participate in the development of their city and shape its policies (Allam and Dhunny, 2019).

This suggests that the digital revolution and appearance of smart cities can cause particular problems for low-skilled people. Although, as remarked by TWI2050 (2019, p. 24) "…historically, technology has created more jobs than it has displaced…", this time things are likely to be different. There is no clear solution to this problem, although many countries have started to look for it. Thus, although we hope that the smart city will yield faster development, it may be associated with increasing unemployment. Digitalization and automation, combined with machine learning and artificial intelligence, will mean that people are no longer necessary not only for low-skill jobs, but also for all routine jobs (e.g., parking guards, salespersons, bus drivers). Some of these outcomes become visible during the pandemics, which lead to a greater automation of human labor – e.g. automatic cash registers in stores, autonomous delivery, etc. Education can help to alleviate this process, but not everybody is willing, interested, or able to obtain new skills. One of the potential solutions is to introduce a basic income (see e.g., Van Parijs and Vanderborght, 2017); however, this is a very controversial idea. Another solution, which is actually closely connected with smart cities, is to move towards a circular economy and circular cities, with new jobs being created in "green industries" (TWI2050, 2019).

The problems of mainly low-skilled individuals are connected with the concept of "digital divide" (TWI2050, 2019, p.25), which concerns inequalities in the "…access to, and usage of, digital technologies…", in benefits

from digital technologies, in knowledge and in power. Another group which is affected by these problems and, thus, is a part of the digital divide is that of older adults (Mitzner et al., 2010). It was well visible during the pandemics lockdown in the first half of 2020, when enforced isolation moved so many elements of lives suddenly into the digital sphere – e.g. health care, public administration services, shopping, etc. Actually, digitalization may reduce these problems, but it has to be well managed. Artificial intelligence can also be an issue in this context, so long as it improves and develops existing models, instead of looking for completely new ways and paradigms (Inclezan and Pradanos, 2017), although some people doubt if AI will be able to design plans for such new ways (Batty, 2018). Nevertheless, the main problem is with access, in particular in the developing world and in poorer regions of developed countries. The diffusion of digital technologies is very fast, much faster than traditional technologies. This helps in spreading information, but also in spreading norms and values, and thereby access may also increase literacy and numeracy in developing countries. Still, in order to overcome the digital divide, governments must be more active in creating the relevant infrastructure, educating people, and providing fitting regulations.

Of course, what was said about the concept of smart cities concerns developed countries, partially because of the costs of new technologies and the lack of the necessary level of technical knowledge in developing countries, partially because those cities are facing different challenges. As Barro et al. (2018) point out in their analysis of African countries, cities in these countries should not try at all cost to become "smart". Nor should they just imitate other cities in their countries, "…which lead[s] to the functional duplication and failure of formulating a complementary relationship between cities…" (Li et al., 2018, p. 2). Instead, they should adopt and adapt the solutions from developed countries and other cities, fitting them to their particular conditions and planning their future development to achieve sustainability. This is also true for cities in poorer European countries, first of all those outside developed metropolitan areas. They do not need a revolution, assuming that they can afford it, since those efforts would in most cases be wasted. A gradual step by step approach seems to be much better, one pursued according to plans having clear objectives. Nevertheless, there is a danger that with such an approach they will be left behind by more developed metropolises (Munoz and Naqvi, 2017), and it is a role of government to prevent this.

Another challenge connected with smart cities and in particular with ageing populations is that, although the smart city can solve many problems of the ageing world, many older people do not see any need for using such sophisticated technologies or are even afraid of them. Although some studies "…contradict stereotypes that older adults are afraid or unwilling to use technology…" (Mitzner *et al.*, 2010, p. 1710), it seems that if they are to accept a technology they must be persuaded that it is useful and easy to use (Mitzner *et al.*, 2016). Therefore, smart cities and industry must offer technologies and tools fitted to the needs and the capabilities of seniors, although such specially designed devices may be quite costly. They should also plan advertising and educational campaigns, including possibilities to experience the technology, and involve older adults in their planning and development. But not even this guarantees success, as shown by the case of Oulu, Finland (Skouby *et al.*, 2014; Suopajärvi, 2017). This is a city which provides a wide range of services to the elderly, concerning their health, wellbeing, activity, and education using modern technologies like the Internet of Things (sensors), mobile devices, dedicated Internet platforms, etc. They are all implemented and managed in active cooperation with older adults, like senior councils, Urban Living Labs, etc. Nevertheless, "…workshops based on the methodology of participatory action research …" (Suopajärvi, 2017, p. 387) have shown that for the senior citizens of Oulu there was a problem of lack of communication between them and the city. The most important issue turned out to be the publication of an information magazine targeted at older citizens. This does not mean that other solutions were not useful. However, even if the elderly see the

usefulness of the new services and know how to use them, they may reject them, since they are designed for old people. In other words, using them means admitting that one is old and this can be stigmatizing (Gopnik, 2019).

In addition, collecting and processing large amounts of data raises the issue of their **quality** and **security**. The large scale of data does not necessarily come together with their quality. If the data on which artificial intelligence algorithms learn is biased, the resulting models will also be biased and may lead to incorrect decisions. Therefore, to make a fully responsible and informed decision, one should know on which database the algorithms were trained and what they were learning. For years numerous reports by ProPublica or the New York Times exposed the scale of **algorithmic bias** (discrimination) for example in criminal risk assessment, predictive policing (Selbst, 2017), credit lending, hiring, etc. (O'Neil, 2016). Understanding the "reasoning" of algorithms is necessary to build trust, which in turn is necessary for people to accept automation in subsequent spheres of life (Morley et al., 2019). Our ability to understand system decisions is also crucial for protecting civil rights and freedoms. When system operators and citizens know how the algorithm works, the chance that it will reflect stereotypes, prejudices, and cognitive errors is reduced. And most artificial intelligence algorithms are black boxes – they do not allow for interpretation between the input data and the outcome (decision). In recent years, however, some new tools have been under development to enhance the explainability of machine learning algorithms (eXplainable Artificial Intelligence, XAI) – see e.g., Holzinger et al. (2017), Adadi and Berrada (2018), Samek et al. (2019) or Biecek and Burzykowski (2019). They even allow for models that are a "black box" to draw conclusions about the relationship between individual features and the target variable, to verify how sensitive forecasts are with respect to a change of the value of explanatory variables, and to show where the specific forecasted value for a given observation came from (which variables influenced the outcome the most and in what way).

Collecting and processing information in real-time using many different devices raises the issue of maintaining privacy and protecting the system against cyber risk. Privacy is considered a fundamental human right in democratic countries and is protected legally and constitutionally (Diggelmann and Cleis, 2014). However, the continuous advancement of technology may mean new opportunities for privacy invaders. Development of COVID-19 tracking software is a good example. Many countries and firms created their own applications, with some of them raising doubts about the security of program and the full anonymity of the data. That is why modern safeguarding solutions that anticipate technological change are needed. Ølnes (2017) suggests that blockchain technology can be used as a platform for various applications in e-Government. This is a peer-to-peer distributed ledger technology originally developed to support crypto-currencies. However, it can be used for any form of transactions that do not require an intermediary (Marsal-Llacuna, 2018). The most important benefit of blockchain is its distributed nature – to successfully attack the blockchain network an invader has to hack more than 50% of the system elements, which is computationally impractical.

Ethical considerations

The question of privacy and all the problems related to it are the biggest ethical problem of the smart city (see e.g., Bunders and Varró, 2019 or Ryan and Gregory, 2019). Municipalities gather data but the process is not transparent, inhabitants do not really know what data is gathered and how it is used. This is not only a question of how much the authorities know about people. Since cities cooperate in smart cities' solutions with IT companies (sometimes they are even seen as dependent on these firms), the question is how much

the firms know and how they use the data. The data can be sold to other firms, it can also be sold by municipalities themselves in order to finance new technologies. Thus, although sometimes, as it was during the COVID-19 pandemics, people may agree to share more personal information with the authorities and firms, they are afraid they have no control on what happens with their data. For this reason most cities try to act according to the principles of data minimization, gathering only necessary data, of anonymization of data, and of the transparency of data-driven policies. In addition, data should be open and available to everybody, which not only shows what information the authorities possess, but can also help in designing new applications using this data.

In creating a smart city one has to deal with the problem of the digital divide, which we have described above. This is a problem for governments on various levels, and most likely one they cannot fully overcome. In practice, some increase of the digital divide is unavoidable, whenever a city imposes fees or subscriptions for access to smart city technologies and solutions. Hence, we have to decide how to proceed with those who do not have access to or do not have the benefits of technology, although they can benefit indirectly from some smart city solutions (McKinsey, 2018). This is not only the case of those who do not have enough knowledge, like the elderly, or cannot afford buying the necessary equipment. In each city there are also people who choose not to be involved, who do not want to use technology. Can we leave these people outside the system or should we somehow force them to join it, by providing them with tools, education, assistance or by threatening them with sanctions? Similarly, in connection to the privacy concerns discussed above, some people may wish not to share their data with the system or want to exercise their right to be forgotten, which can restrict their access to the system.

Another ethical problem we have to consider is that such a close connection between people, IoT, and AI entails a blurring of boundaries (Pitroda and Miailhe, 2017, p. 3). We will have to decide where a person ends and a machine starts, if they can be separated at all, and, with the development of AI, what are the rights of a machine and whose voice should be listened to. For example, we hope that with these technologies older people will remain independent and more active. Will this be the case when they cannot be separated from the machines, i.e., from sensors, robots, and constant monitoring though the net?

Costs

The costs of creating the smart city pose the biggest obstacle to the project, at least for most municipal governments. They do realize that there are also other challenges, ones we have mentioned above, but since most cities are in the initial stage of smart transformation, they are likely to take a secondary place. It is impossible to assess the full cost of transforming a city into a smart city, assuming that we can precisely define what we mean by this term. However, there are some data we can refer to. For example Pitroda and Miailhe (2017, p. 3) report that "…the AI market is expected to grow to 40 billion dollars annually by 2020…", while according to Zanella et al (2014, p. 23) "…the Smart City market is estimated at hundreds of billion dollars by 2020, with an annual spending reaching nearly 16 billion…". Of course only a portion of this sum will be spent by municipalities, but even a portion of many billions of dollars is a significant expenditure. Still, while some projects may and will cost billions, other will cost much less, like creating the portal for e-services for Warsaw, which will cost about 2 million Euros (Warsaw, 2017). In general, according to Caragliu and Del Bo (2019, p. 375) in recent years in the European Union the median smart city projects cost around 10 million Euros with half of this amount provided by the EU.

Such small projects, which can have a considerable impact on the quality of life, are within the reach of most cities. Nevertheless, a city has to consider not only the costs of new hardware and software, but also the employment of specialists who can use them. Even assuming that the systems are user friendly and can be used without much technical expertise, the technology, including AI, can only provide information and observe patterns while the municipal authorities must be able to make decisions and formulate plans based on this data (e.g., Inclezan and Pradanos, 2017, Allam and Dhunny, 2019). Many cities admit that they are not able to do so, since they are not able to analyze the data the technology is gathering for them (Smartpolis, 2018; Bunders and Varró, 2019). This requires specialized expertise, which elective officials do not necessarily possess, thus they have to hire it. The costs are additionally increased by the lack of common standards, no compatibility between different technologies and systems. No doubt they will be developed in the future. However, for the moment this leads to inefficiencies and wasted resources, since municipalities are trying to evaluate, assess, and combine different solutions in their smart city projects (Li et al., 2018; Smartpolis, 2018).

While considering the smart city projects, municipalities have to take into account two problems: how to finance their new investment projects and how to maintain them once they are operational. In many EU countries the accessibility of European funds in various forms and through differing programs make them the main source for funding these projects, crowding out other financial options (Smartpolis, 2018). However, the paradox of EU funds is that it may be easier to build something than to cover the costs of operations. As Saxe (2019) points out, this is extremely important, since technologies are ageing rapidly and maybe it will be necessary to replace technologies every few years, what dramatically increases the cost of smart cities. Small cities in particular may be not able to bear such costs. Thus, these projects often cannot be implemented without the participation of the private sector, which possesses not only the capital but also the necessary expertise. McKinsey (2018) judges that 60% of initial investment in smart city applications could come from private entities. Whenever the private sector is involved, municipal authorities must decide on the payment method. The difficulty lies with the assessment of future revenues from the project. McKinsey (2018) estimates that over 50% of initial investment by the public sector can yield revenues, not only in the form of eventual service fees, but also of reduced costs and the increased efficiency of public services. Such revenues may be hard to estimate and in some cases even impossible to imagine before they actually appear. According to Deloitte (2018, p. 10) the four most effective revenue models are that of advertising via the service, subscriptions, user fees, and selling the data gathered by the service. However, all of them yield the ethical problems mentioned above.

The role of governments, regulations, and EU policy recommendations

One of the problems of smart cities is who will provide technologies and the tools for using them. This is not an issue for rich people, who are likely to gain the most from these processes, but for the poor and the elderly it is very important. This may change in the future, but for the moment those in the latter two groups do not have the resources and knowledge to make optimal choices while choosing technologies and buying the necessary equipment. Therefore, if we do not want them to be excluded from all the benefits of smart cities, other entities must provide them with access to these benefits. These can be done by either the public sector, i.e., the central or regional government, or municipalities, or the private sector, which often means tech-giants. In both cases we need rules to ensure universal access, to guarantee privacy, and to protect individuals against cyber-piracy and the misuse of the information gained by the providers.

There is a need for new ways of sharing knowledge and information about various ideas and solutions between municipalities, regions and countries, possibly even for rules forcing them to share it. This offers some protection against the possibility that some municipalities will try to develop at the expense of others, in particular where artificial intelligence is concerned (e.g., Munoz and Naqvi, 2017; Vinuesa *et al.*, 2019). There is an obvious demand for European platforms for the exchange of information, horizontal platforms through which cities can learn what municipalities in all other EU countries are doing and choose solutions best fitted to their needs. The EU should also help national government in supporting smart city initiatives financially, in particular in less developed regions and in poorer municipalities. One possible tool for this is that of cohesion funds; however, they are likely to be reduced in the new financial prospects. In addition, in such support we should abandon the often preferred rule that "one solution fits all" (Szlachta and Zaleski, 2017). On the contrary, in this field each solution should be fitted to the situation of a particular municipality and its development plans.

In the case of public sector provision, new rules for public procurement may be necessary in order to ensure access to the optimal level of technology with minimum costs. Common rules for the whole European Union would be useful in this respect, in particular by promoting the solutions developed by small, local firms and non-governmental organizations, and by making it easier for them to compete across the whole Union. Moreover, the public sector will have to employ new types of knowledge and expertise, which in practice means paying more to their employees in order to be competitive on the labor market. Without such experts the effort to regulate new markets and new technologies may fail, since as Vinuesa *et al.* (2019, p. 8) put it "…regulatory oversight should be preceded by the regulatory *insight*…"

In the case of private sector provision, we cannot simply rely on market rules, since this is a clear way to excluding a part of society from the benefits of smart cities. This is a classical case when a private sector supply can be insufficient and too costly. Therefore the government on different levels should intervene, regulating and subsidizing private firms in order to lower the prices for individuals and increase the supply. This is a very similar process to what many countries are doing now to ensure internet access even in those areas where from the commercial point of view it does not make much sense. However, there is another aspect of these processes that we should consider, although it is very controversial – namely, regulating tech-giants and using anti-trust laws against them. According to Miailhe and Hodes (2017) the current trends suggest that in the future AI will be controlled by a global oligopoly of a dozen multinationals. Munoz and Naqvi (2017), in discussing the development of artificial intelligence, suggest splitting such tech-giants into smaller, non-monopolistic firms. However, this is not only a problem of artificial intelligence, since even without it these are the tech-giants who will provide the majority of technologies and tools necessary to develop smart cities. In the process they will gain immense power, since cities and their inhabitants will be completely depended on them. This is connected with a luck of the trust necessary in creating a smart city, since the motivation of these firms is rather in gaining a market advantage and increasing profits and not in improving the quality of living in cities (Allam and Dhunny, 2019). It seems logical that the solution to this problem should be developed on the European level and not by individual countries.

A very important role for cities, governments, and the EU is to educate their citizens and to develop new education for people living in the new "smart" world. Many jobs will become redundant, but new opportunities will appear, in particular in the technological sector and in services. Current educational systems are not really preparing people for such future. True, today's children will be much better adjusted to living with technology than today's adults, but the processes currently taking place will demand a

completely new level of technological literacy. Without it many people will be excluded from the benefits of the technological development and will feel/be redundant in smart cities. We have to work now to devise new educational approaches in order to prevent discrimination in the not-so-distant future.

Summary

The concept of the smart city responds to the challenges of the modern world, though as a whole it seems to be rather more a futuristic vision than a reality that can be applied in every city. Selected solutions are being successfully implemented in global metropolises and smaller cities, and the COVID-19 pandemics was a good example that the process can progress very fast, but many of them raise new concerns and problems. An important role of scientists and decision-makers is to propose solutions that respond to the real needs of city dwellers and at the same time address global civilizational challenges, as well as to ensure the safety of proposed tools. An important barrier to the development of this type of technology is that of the still high costs and lack of regulation. Low deployment costs (also in the environmental-impact sense) are a key factor for the sustainability of smart city solutions. They also need to be safe, reliable, scalable, inclusive, and transparent to citizens. As such, the smart city may bring a number of benefits in the management and optimization of traditional public services in cities.

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