

BRINGING “SMART” INTO CITIES TO FIGHT PANDEMICS – WITH THE REFERENCE TO THE COVID-19

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ABSTRACT: *The outbreak of Coronavirus Disease 2019 (COVID-19) has affected the lives of 5,698,246 people globally. Originating in China, the virus progressed rapidly to other countries. The COVID-19 outbreak has mostly affected cities and seriously threatened citizens' health, the economy, and the infrastructures of the urban territories. Several states were relatively quick to deploy smart technology solutions to respond to the emergence of COVID-19. Existing and new digital technologies are proposed to supplement the traditional measures within the response to the first pandemic of the decade. The term smart technologies imply the Internet of Things (IoT), Big Data, and Artificial Intelligence. The focus of this paper was to propose smart technologies as a part of the solution toward reducing the spread of pandemics in urbanized areas. One of the aims was to find positive examples of the smart city implementation during the pandemics and show its usefulness in facing it. The possibility of using real-time data, thus conducting real-time action is their main advantage and that is why more cities should use this smart concept to respond to the global crises.*

Keywords: *smart city, COVID-19, Big Data, Internet of Things, Artificial Intelligence*

INTRODUCTION

In December 2019, several local health authorities reported clusters of patients with pneumonia of unknown cause. The patients were epidemiologically linked to a seafood market in Wuhan, Hubei Province, China (Cui et al., 2019). On 30 January 2020, the epidemic of coronavirus disease 2019 (COVID-19) was declared as a Public Health Emergency of International Concern, the highest level in the World Health Organization's

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(WHO) emergency response for infectious diseases. Six weeks after the declaration, the outbreak was categorized as a pandemic. The number of cases was accelerating in China and subsequently all over the world. According to WHO Coronavirus Disease 2019 (COVID-19) situation report on 27 May 2020, 5,698,246 cases have been documented globally, with 352,461 fatalities and counting (<https://www.who.int>). Strikingly, COVID-19 had been transmitted in more than 205 countries to date, including Asia, Europe, North America, South America, Africa, and Oceania. The emergence of a novel coronavirus has led to a global response to the first pandemic of this decade.

Porta (2014) defined pandemic as an epidemic that comes over a very wide area, going beyond international boundaries, and affect the lives of many people. Therefore, pandemics are identified by their geographic scale rather than the severity of illness. In contrast to annual seasonal influenza epidemics, pandemic influenza is defined as a new influenza virus that appears and spreads around the world, and people do not have immunity yet (WHO, 2010).

Cities face immense challenges that require smart solutions to be implemented. The best measures for controlling and suppressing the epidemic until the development of the vaccine are so-called “social distancing” and extensive usage of protective gear (Kummitha, 2020). The implementation of these two measures depends on the level of city development. However, social distancing in a modern world with large agglomerations can be challenging measures to perform due to high population density. On the other hand, the usage of various online communication tools and information technologies was shown as a serious and reliable way of dealing with global problems like this one. Modern digital technology, like mobile phones, data analytics, and social media, offers a unique set of tools to help manage pandemic lifecycles. Source (Mboup, 2019).

Nowadays, traditional cities are going through serious urban challenges, ranging from environmental, economic to social challenges. However, current modern cities are more resilient than ever before. This is due to the increased adoption of smart technologies such as the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI), that provide the technical framework for making cities smart (Kummitha, 2020). Moreover, smart city initiatives need big data analytics to function (Giffinger et al., 2007).

A smart place, either a city or a building, is often described as being capable of managing its resources intelligently, and it is often based on the notion of technological-interconnectedness (i.e., IoT) (Vermessan and Friess, 2014). The International Data Corporation – IDC (2018) defines smart city development as investments in powerful technology across the whole city while having the same efficiency, systems, improvements as well as smart utilization.

Speaking about indicators of smart cities, Giffinger et al. (2007) and Cohen (2012) defined six most-common indicators that are built on the ‘smart’ combination of endowments and activities of self-decisive, independent, and aware citizens. These indicators are (1) smart people, (2) smart governance, (3) smart mobility, (4) smart environment, (5) smart living, and (6) smart economy. In one sentence the smart city is a constellation of “technology, people, and institutions” Nam and Pardo (2011). Cities with available educated labor force enjoy faster urban growth since they are skilled enough to manage different systems and unexpected situations (Letaifa, 2015). As for technology, it is a

useful tool for making the city greener, safer, and effectively planned. Big data can help cities to monitor and manage urban issues such as waste disposal, transportation, and saving resources. Obtained and analyzed data should bring tangible services and solutions to citizens. In contribution to this, there are social networks that can provide real-time information about the situation. These facts imply that city management will need to be data-driven, which in turn enables a better functioning of urban environment, better connectivity, faster response, and troubleshooting (Maksimović, 2017). The smart city represents the future challenge, a city model where the technology is in service to the person and tends to improve the quality of his economic and social life.

Smart cities host a rich array of technological products that can assist in early detection of outbreaks, for instance through thermal cameras or IoT sensors. The integration of thermal cameras with AI can provide greater benefits hence thermal cameras are not sufficient on their own for the detection of diseases like COVID-19 (Allam and Jones, 2020). Some reports claim that instead of a future after the COVID-19, it will be a future with it (Sneader & Singhal, 2020). This may translate into a major rethink about how people can live and work at high densities in towns and cities, including the need for and provision of transport, leisure, and open space.

The paper reviews relevant literature that support the argument of smart cities as a possible solution in dealing with the pandemic and to emphasize the advantages of a smart building, community, and living. The subject is smart technologies integrated into cities suitable for fighting pandemics as well as their utility in managing collected data and using it most effectively. The aim of this paper is to assemble the literature and point out the ability of technology to address societal challenges and contribute to operational efficiency, information exchange with the public and improvement of government services, and citizen welfare.

THE BIGGEST PANDEMICS IN HISTORY AND ITS CASUALTIES

Pandemics are outbreaks of infectious diseases that can seriously increase morbidity and mortality over a wide geographic area. Evidence suggests that the likelihood of pandemics has increased over the past century because of increased global travel and integration, urbanization, changes in land use, and greater exploitation of the natural surroundings (Morse, 1995). These trends will likely continue and be more intensive.

Among the best-known pandemics is the Black Death, a plague that spread across Asia and Europe in the middle of the 14th century. The Black Death was a devastating global epidemic of bubonic plague in the mid-1300s. The plague arrived in Europe in October 1347, when ships from the Black Sea docked at the Sicilian port of Messina (Byrne, 2004). The estimated number of deaths ranges from 25 million to 100 million, or between 30% and 50% of Europe's population (Cohn, 2008). Today, the tragedy of the Black Death offers a unique opportunity to scrutinize past human health and the social impacts of pandemics. Europe had been overpopulated before the plague, and a reduction of the population have resulted in higher wages and more available land and food for laborers because of less competition for resources (Byrne, 2004). Furthermore,

the plague's great population reduction brought cheaper land prices and more food for the average peasant. The second major consequence was the economic loss that resulted from the spread of the plague. For example, some of the hardest-hit areas were trading ports. The spread of the plague caused people to avoid crowded areas. Hence marketplaces and trade in general suffered. Plague is now treated with antibiotics and can be prevented by applying insecticides. However, if left untreated, it remains a disease with a high mortality rate.

Since the beginning of the 20th century, the most severe of pandemics was the influenza pandemic, so-called "Spanish Flu", estimated to have caused up to 100 million deaths in 1918–1919. Milder pandemics occurred subsequently in 1957–1958 (the "Asian Flu") and in 1968 (the "Hong Kong Flu"), which were estimated to have caused 1-4 million deaths each (Wang-Schick, 2017). The influenza pandemic of 1918–1919 was brief but severe. The pandemic first appeared in the United States during the spring of 1918. The virus infected an estimated 500 million people worldwide, one-third of the population (Johnson and Mueller, 2002). In the United States, fatalities were between 675,000 and 850,000, more than 30% of the country's population (Kolata, 1999). Spanish flu brought illness, death, and loss to tens of millions of people around the globe and is the worst pandemic in recorded history (Crosby, 1989). However, it also raised awareness about improving public health, which led to advances in medical sciences, public health planning, and international cooperation.

In 2002, a pandemic of SARS occurred endangering the lives of 8098 individuals with a mortality of 774 patients (Paules et al., 2020). The epicenter of the disease was Guangdong, China, from where it spread to more than twelve countries. The human-to-human airborne transmission was perceived, and strict public health measures were employed (Paules et al, 2020). The first influenza pandemic of the 21st century occurred in 2009–2010 and was caused by an influenza A(H1N1) virus, also known as swine flu. While most cases of pandemic H1N1 were mild, globally it is estimated that the 2009 pandemic caused between 150 000–575 000 deaths. Number of the infected people across the globe was 1.4 billion. The swine flu primarily affected children and young adults, and 80% of the deaths were among people younger than 65 (Mukherjee et al., 2015). In this case, older people seemed to have already built up enough immunity to the group of viruses that H1N1 belongs to, so they were not affected as much. It was the first pandemic in history for which many states had developed comprehensive pandemic plans describing the public health measures to be taken. For the first time, the pandemic vaccine was developed and deployed in multiple countries during the first year of the pandemic (WHO, 2010).

In September 2012, a rapid-spreading infection, MERS, emerged in Saudi Arabia. Unlike SARS-CoV, which rapidly spread across the globe, MERS has smoldered, characterized by sporadic zoonotic transmission, and limited chains of human spread. According to the World Health Organization, as in November 2019, MERS-CoV has caused a total of 2494 cases and 858 deaths, the majority in Saudi Arabia. Mechanical ventilation was given to 50%–89% of patients, associated with a mortality rate of 36% (Paules et al., 2020).

On March 11, 2020, the WHO announced that the COVID-19 virus was officially a pandemic after barreling through 114 countries in three months and infecting

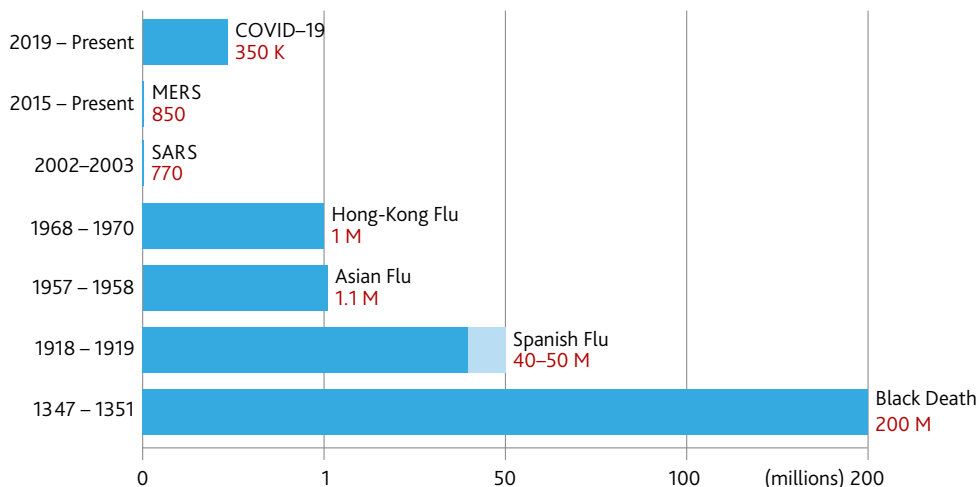


Fig.1 Selected pandemic death toll overview

Source: <https://www.visualcapitalist.com/history-of-pandemics-deadliest/>

over 118,000 people. The pathogen, a novel coronavirus (SARS-CoV-2), was identified through a report of several pneumonia cases by local hospitals in Wuhan. (Li et al., 2020). Coronaviruses (CoVs) can infect animals and also humans, causing respiratory, gastrointestinal, and neurologic diseases (Weiss and Lebowitz, 2014). Coronavirus belongs to the family of Coronavirinae, order Nidovirales (Chen et al., 2020). Until 2019, only six human coronaviruses (HCoVs) were known as being responsible for respiratory diseases. Like SARS-CoV, MERS-CoV, and many other coronaviruses, SARS-CoV-2 likely originated in bats, but it needs further confirmation whether it is transmitted directly from bats or through an intermediate host (Jin et al., 2020).

The crisis did not come without warning. SARS, H1N1, MERS, Ebola, Zika, all reminded us of the eventuality we are now experiencing. Although pandemics and plagues can undermine cities, history showed us that the cities bounce back stronger and forceful. After every pandemic, there is a need to build innovatively, to promote healthy spaces and smart density.

DEVELOPMENT OF SMART TECHNOLOGIES AND THEIR IMPLEMENTATION IN URBAN ENVIRONMENTS

The difficulty with the clarification of the term “smart city” is that there is a gap in the existing literature. So far, the literature mostly neglected considerations of the policy and managerial side of innovation, addressing only the technological aspects of the smart cities. Additionally, various keyword terms have been used as synonyms to “smart city”, which makes the concept of the smart city quite indistinct (Nam and Pardo, 2011). Several definitions have been put forward for the “smart city” concept: these definitions were generated from many different disciplines (Albino et al., 2015). According

to Giffinger and Gudrun (2010), the smart city is “a city well-performing in a forward-looking way in various characteristics, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens”. Hartley (2005) considered that only a city that connects the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city can be characterized as smart. The mission of a truly smart city is to improve the quality of life for citizens and visitors (Maddox, 2018).

The expansion of cities in the modern world faces a variety of challenges. Although cities occupy less than two percent of the earth’s landmass, urban inhabitants consume more than three-quarters of the world’s natural resources (Nam and Pardo, 2011). Technologies, that enable sustainable development in cities and their application, are an integral part of the Smart City concept. The information and communication technologies (ICT) can provide more feasible solutions to some of the problems faced in cities, especially for emergent situations in big cities. The combination of useful data being used by smart tools allows smart cities to grow (Kondepudi and Kondepudi, 2015). Kamel Boulos et al. (2019) supports that data from various technological products can enrich health databases, provide more accurate, efficient, and real-time information in order to stop chains of transmission.

From an ICT perspective, the term “smart” in a smart city implies the use of Internet, IoT, and Big Data. According to Vermessan and Friess (2014), IoT is a concept that considers interrelated computing devices, mechanical and digital machines that through wired connections and unique addressing schemes can interact with each other without requiring human-to-human or human-to-computer interaction. Internet plays a fundamental role in communication, information sharing, and processing, data transfer, and analysis. Data is the most valuable asset for a smart city. Based on acquired data, smart cities will be able to monitor vital city services and act in real-time. Big data is defined as “the information assets characterized by such a high volume, velocity, and variety to require specific technology and analytical methods for its transformation into value.” (De Mauro et al., 2015). The data needs to be gain not only from sensors but from citizens themselves. Citizens are active actors and final users of smart city services and play a fundamental role in improving the urban ecosystem and addressing their challenges.

There is a possibility of forecasting the spread of the COVID-19 outbreak by utilizing data from digital services. Mobile-phone data already showed potential in predicting the spatial spread of the disease during the 2010 Haiti cholera epidemic, while leveraging big data analytics showed effectiveness during the 2014–2016 Western African Ebola crisis. In those cases, big data and mobility data helped to track the disease and create a quick response. The limitations were related to the deficiency of devices that enabled tracking of individuals. Nevertheless, having such data benefited public health (Altaweel, 2020).

Smart cities as a response to pandemics

In epidemiology, Geospatial Artificial Intelligence (GeoAI) has been used to describe and analyze the spatial distribution of diseases and to study the effect of location-based factors on disease outcomes. (Kamel Boulos et al., 2019). As an example, the WHO has

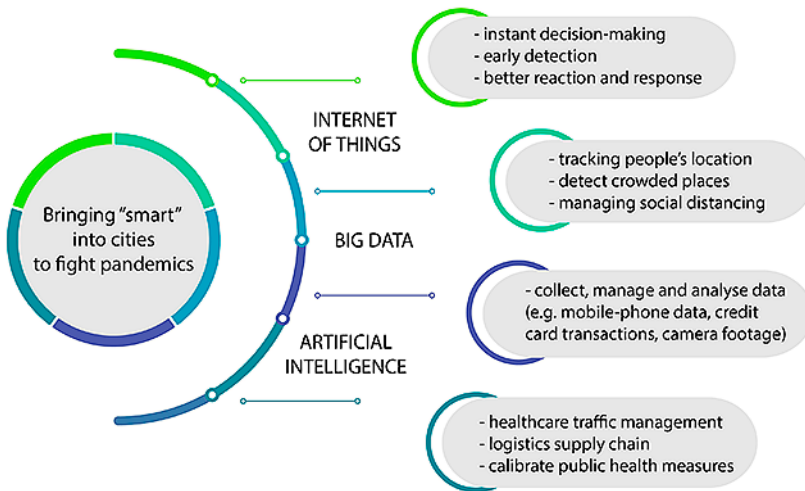


Figure 2. Smart city technologies and their implementation

been applying geospatial mapping tools for global applications, including for the Ebola virus disease outbreak in 2014, to monitor and to respond to the emergence of new disease cases in different countries over time.

Related AI technologies could be applied to support diagnosis and treatment, and to ensure minimal disruption of people's lives (Xu et al., 2020). The integration of health big data with city IoT infrastructure and GeoAI tools can allow local authorities and policymakers to better city development plans to distribute and improve health and transportation services. (Kamel Boulos et al., 2019). For instance, constant visits to transportation hubs might indicate the need to add additional buses or trains in order to maintain a social distance. Therefore, GeoAI technology could have a vital role during this outbreak in almost every aspect, such as traffic management, infection detection, logistics supply chain, etc., which is a very important characteristic for a modern data-based smart city (Fig. 2).

IoT-powered smart cities rely utterly on the sensors' usage that can be embedded into buildings, roads, vehicles, devices, and human bodies turning these physical objects into digitally connected "things". These IoT sensors deployed in cities lead to the generation of a huge amount of real-time data, which are often geo-tagged or geo-located. The comprehensive analysis of these geo-tagged IoT data allows local authorities to identify the most crowded areas in the city at different times, enabling instant decision making (Varmessan and Friess, 2014).

Some cities (like Vilnius) are planning to dedicate street space for outdoor seating to help restaurants and cafes operate within physical distancing constraints. Smart cities already use various smart city applications, which demonstrate their initiatives to involve their volunteering residents. A sensing network of volunteering city residents can be used to perform crowd-sensing (Pouryazdan et al., 2016). The main aim of the crowd-sensing is to incorporate the sensor data from the participating smartphones by collecting the data from the nearby smartphones, merging this data into the smart box, and

sending them to the city IT center (Pouryazdan et al., 2016). With savvy use of smart technologies, it would be possible to facilitate early detection, achieve a better diagnosis, and potentiate better respond for increased for virus containment.

Maps are more and more involved in decision-making processes in emergencies; hence they provide the required real-time information. Robust COVID-19 surveillance data are essential to calibrate appropriate and proportionate public health measures. Some of the possible actions are: (1) to conduct an initial capacity assessment and risk analysis, including mapping of vulnerable populations, (2) map available resources and supply systems in health and other sectors, (3) map vulnerable populations and public and private health facilities (including traditional healers, pharmacies and other providers) and (4) identify alternative facilities that may be used to provide treatment (Kitchin, 2020). Location is the main demand when aiming to monitor and map the spread of disease. Since the outbreak of the coronavirus earlier this year, many apps have been developed that use location data to monitor the global spread of the disease (www.gsa.europa.eu). There are many ways to obtain location data: (1) cell-site location information (CSLI) that records phone connections to nearby towers, (2) GPS signals, (3) Wi-Fi connections, and (4) Bluetooth (Kitchin, 2020).

One of the innovations and changes during the pandemic was the adequate and flexible design of public spaces and streets that allow residents to engage with the outdoors while maintaining social distancing. New infrastructure should follow established guidelines for safety. Many cities have rapidly repurposed streets to provide safe room for pedestrians, cyclists, and other forms of light, active mobility. The problem is that big cities are not adapted to current physical spacing guidelines imposed by COVID-19, and these measures cannot be entirely and fast adapted. As more countries are preparing to use digital technologies in the fight against the ongoing COVID-19 pandemic and implement it in solutions, data and algorithms could be the main weapon in this fight as well as in the fight with the latter pandemics.

Romanian company RISE has developed an app called CovTrack, which stores the identification data of the devices in person's vicinity via Bluetooth technology. When a new patient is tested and detected positive for COVID-19 the medical staff needs to enter his phone's unique Bluetooth address in a central database. Similarly, Singapore has launched TraceTogether, a contact tracing app that detects and stores the details of nearby phones and claims to be the first national Bluetooth tracing solution in the world. Despite the government's public campaign to the country to download the app, only 12% of the population installed it.

Other nations like China, Poland, and South Korea are using high-tech methods of contact tracing that involve tracking peoples' locations via phone networks. In some municipalities in China, it was required to install an app that has a QR code. Every citizen is assigned a QR (also known as Quick Response) code, which allows the app to track their location. When citizens use public services such as public transportation or visit a supermarket, they need to scan their QR code. The app works by assigning a color code (green, yellow, or red) based on the user's travel history and health status. Green codes mean that citizens can have unrestricted movement, while yellow and red codes are indicators that the user needs to be quarantined for seven or 14 days (Kummitha,

2020). Overall, the AI systems are highly efficient and a source of relief for the overstressed health system in China. Human rights experts, for instance, argue that the extreme surveillance measures followed in China may not work in other countries, as they impose severe restrictions on the human rights of the citizens (Kupferschmidt & Cohen, 2020). While China largely focused on identifying those who are infected, Western democracies have focused on a human-driven approach, comprises of collecting anonymous data, ensuring lockdowns, and quarantine (Kummitha, 2020).

Following China's example, other governments have also turned to similar technology to battle the virus. The Polish government launched an app that requires people in isolation to take a geo-located picture of themselves within 20 minutes of receiving an SMS or risk a visit from the police. It prompts you to take a straight-face real-time picture at the address you have provided to the authorities. By using geolocation and facial recognition algorithms, it can be concluded whether you're at your quarantine residence or not. (Kummitha, 2020). The real problem is that there is little transparency in how these data are cross-checked and reused for surveillance purposes.

Government bodies in Italy can track down patients since their citizens generally use the unique personal identification number for accessing healthcare facilities. These data are typically handled by different uncoordinated regional and national healthcare institutions hence Italy has faced a situation where the absence of coordination between different healthcare departments has resulted in the failure of using available big data effectively (Carinci, 2020). There is an urgent need to work towards the standardization of protocols in order to leverage big data in smart cities.

In South Korea, the government is utilizing surveillance camera footage, smartphone location data, and credit card purchase records to track positive cases and their contacts (Fendos, 2020). Corona 100m (Co100), launched in February 2020, is Korea's most popular mobile app related to corona virus outbreak. It alerts users when they come within 100 meters of a location that has been visited by an infected person. South Korea also plans to build out a "smart city" database that will give real-time data on patients, including their location, time spent at specific locations, CCTV footage, and credit card transactions (Smith et al, 2020). But such centralized, surveillance-based approaches are viewed as invasive and unacceptable in many countries for privacy reasons.

Big data is collected by large mobile apps that have a potentially great benefit in combating the spread of COVID-19. However, there are raised concerns about how these data are used and stored, and how are they going to be used in the future, particularly if these data are not used for public health reasons (Altaweel, 2020). More data collection is going to raise further questions and concerns in terms of the risk of violating privacy and other fundamental rights of citizens, particularly when such measures lack transparency and public consultation. Governments also need to ensure that the increased collection and use of data will be temporary and the activity will stop once the situation comes under control. In addition, it is crucial that data is stored on an individual's device and encrypted. Hence, by following this guidance, governments will be able to assure their citizens about the responsible use of personal data (Kummitha, 2020).

CONCLUSION

Recently, civilization has been facing grand challenges including climate changes, extreme natural disasters, social disturbances, and pandemics. With each pandemic, people gained a better understanding of the complexity and dynamics of pandemics. The improvement of surveillance systems enabled more data and characteristics of viruses can be documented than was possible a decade ago. COVID-19 pandemic has demonstrated the contradictions and vulnerabilities of our globalized system.

One of the conclusions is that countries need to adopt a broader and long-term vision to improve data systems to help manage mass testing, isolation of sick patients, and managing geographical outbreaks. Data systems should be flexibly designed to adapt to future scenarios. Implementing smart technologies can help manage the spread of the virus and take corrective action. Each country should use outbreak data to manage consumer supplies, hospital beds, sharing of resources between hospitals, and deployment of healthcare workers. With the usage of the appropriate technology solution to collect and manage data, it can be possible to curb the spread of the latter pandemics. For example, Big Data is very helpful for the recognition, monitoring, prevention, and control of new diseases. With real-time data, one can get an insight into the development of the situation and thanks to this can take proper actions in preventing the catastrophe. Relying on this fact there is a need for decision-making and policy-making, which is adaptive, flexible, and well-integrated.

However, during these recent epidemics, the large-scale collection of mobile data from millions of users especially call-data records and social media reports also raised privacy and data protection concerns. Gaining access to data from personal devices for contact tracing purposes can be justified if it has a clear purpose e.g. warning and isolating people who may have been exposed to the virus. The usage of this personal data must be in accordance with the policy of privacy protection, but citizens also must be aware of the importance of data sharing, especially in this situation. On the other side, urban community leaders need to learn from the current situation and develop adaptive solutions on short, medium, and long-term levels, as well as to educate and provide true information to the population.

The COVID-19 crisis could offer a unique steppingstone for a truly inclusive digital revolution for our cities. This pandemic is challenging and forcing a rethink on the tried and tested principles of urban planning like density and compact development. It might lead to a qualitatively new reality for the foreseeable future that is physically spaced, hyper-sanitized, hygienic-masked, and crowd-averse. After COVID-19 cities should bounce back better; innovations should be made to create new safety protocols to keep passengers and public transport workers safe, and investments should be made in extensive service expansions to make the next crisis easier to manage.

This study is opening a large number of questions and provides information about new smart technologies and dealing with the global issue in a different, modern way by using all of the benefits of sharing, comparing, and team working. Once again it is shown that without proper individual involvement in problem-solving there is no qualitative living. When on this, cities add using of smart technologies and invest in their integration, there

is a solution that is above all that has been done and used so far. Exactly this is the point where the community can make changes and act together with the technology.

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CONFLICTS OF INTEREST

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