SMART CITIES DEVELOPMENT IN THE CONTEXT OF SARS-CoV-2 PANDEMIC

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Abstract
The COVID-19 pandemic has affected urban communities, generating the need for various strategies offered by the governments. This paper aims to explore the situation of smart cities in the context of the COVID-19 crisis, focusing on COVID-19 non-pharmaceutical interventions and COVID-19 impact on smart city development. The research is based on an exploratory study and analysis without setting a systematic literature review. The suggested findings are based on expertise in collecting, processing, and analyzing data from different sources. They emphasize the importance of advanced technology, innovation, and collaboration between citizens, public and private entities. Some smart cities adapted their advanced technology and non-pharmaceutical interventions for an efficient response against the COVID-19 pandemic, while others presented a slow response. Smart city projects involve collective learning processes and innovation for a long-term horizon for urban growth. The critical factors in the development of the smart cities market include the growth of urbanization to generate the adoption of various solutions referring to efficient management, demand for fast transport, public safety, a healthy environment, and efficient energy consumption. The paper represents a good source of information for governments, scholars, and researchers. By reviewing the paper, solutions to improve citizens' quality of life could be taken.

Keywords
COVID-19; development; non-pharmaceutical interventions; pandemic; smart cities; smart technology.

Introduction

The Coronavirus Disease (COVID-19) pandemic continues to spread globally. According to www.worldometers.info, on July 17, 2023, globally, there were 691,477,663 total cases, 6,899,719 total deaths, and 664,058,758 total recovered. On the same day, in Romania, there were 3,408,455 total cases, 68,243 total deaths, and 3,339,242 total recovered. The Coronavirus Disease is a constant pandemic threat through its new mutations of the SARS-CoV-2 agent, which produces health, economic, and social issues. COVID-19 has affected almost every industry during the forecast period. It has impacted all business sectors and affected smart cities.

The COVID-19 pandemic affected consumer behavior and demand. It defined new patterns, modified the supply chain, presented the dynamics of current market forces, and introduced new government interventions (Global Data, 2022). One of the main problems in the COVID-19 pandemic crisis is the preparedness of countries to deal with pandemic threats. The pandemic impact on smart city development and operation represents a very complex topic. Research demonstrates that climate and environmental elements, especially air pollution, influence the diffusion of COVID-19 (Ionescu & Ionescu, 2023; Bashir et al., 2020; Coccia, 2020). In addition, smart cities are considered greener, safer, and friendlier. A smart city involves the following smart directions: technology, infrastructure, energy, and healthcare. The role of these elements is to improve the quality of life by ensuring future generations' economic, social, and environmental needs. Internet of Things (IoT) and Big Data (BD) help smart cities be efficient and responsive (Mohanty et al., 2016). All countries have made efforts to handle the pandemic. They have considered medical treatment and COVID-19 non-pharmaceutical interventions of maximum interest. Before the COVID-19 pandemic, the development of smart cities was a higher priority. Apart from the pandemic-correlated investments in technology and medical infrastructure, the evolution of other projects in smart cities was impacted and delayed (e.g., new highways, new parks, smart city-led lighting systems, etc.).

This study aims to emphasize the present situation of smart cities after the COVID-19 non-pharmaceutical interventions as part of managing the pandemic and their future development. The research is based on studies and analysis of existing literature on the effect of the COVID-19 pandemic on smart cities. The manuscript is structured in six sections. Following the introduction, an overview of the present situation of smart cities is presented through a literature review. Then, the methodological section is presented. In the fourth section, results regarding the COVID-19 non-pharmaceutical interventions in smart cities are emphasized, continuing with the COVID-19 impact on smart city development. Finally, discussions and conclusions are outlined.

Literature review

The global smart city market size was forecasted at USD 355.09 billion in 2021 and is expected to reach USD 389.14 billion in 2022 and is projected to grow at a CAGR of 9.76% to reach USD 621.12 billion by 2027 (360iResearch, 2022). The smart cities market is expected to increase at a CAGR of around 22.1% during the forecast period 2022-2027 (Mordor Intelligence LLP, 2022). A smart city is a place where classical networks and services are created to be more flexible and sustainable with the help of information, data, digital, and telecommunication technologies. Through its operations, it offers several benefits for its inhabitants (Mohanty et al., 2016, p.1). A smart city is an innovative place where information, technology, and physical resources meet to create benefits for individuals as well as for the environment.

The individuals' preference to migrate to cities is one of the primary reasons for the world becoming increasingly urban. Cities cover only 2% of the Earth's surface, but they account for 50% of its population, which has encouraged the growth of smart cities (Global Data, 2022). The world population and the expectation of living standards have increased in the last few years. Around 70% of the world's population is forecasted to live in urban areas by the year 2050 (Mohanty et al., 2016, p.2). Hence, smart cities represent a necessity.

The creation of smart cities represents a good strategy to mitigate the problems produced by rapid urbanization. Even though the costs associated with their development are high, once implemented, smart cities can reduce energy and water consumption, carbon emissions, city waste, and transportation requirements. A smart city will include smart citizens, governments, buildings, transportation, technology, healthcare, and energy. A smart city has six necessary fields: citizens, environment, economy, society, mobility, and governance (Moura & Silva, 2019; Mohanty et al., 2016). Smart citizens refer to connected citizens, workers, visitors, e-learning, and e-health. The environment field of a smart city suggests that the city will sustain water and waste management, sustainable processes and urbanization, and monitoring of environmental indicators. The economy indicates that the city thrives with continuous economic growth. The society field of a smart city signifies that the city helps its citizens and addresses their needs. The smart mobility field refers to intelligent transportation and parking systems, traffic management, and mobility as a service. The governance field implies that the city is good in its ability to manage policies, open data, and digital automatization of processes (Moura & Silva, 2019; Mohanty et al., 2016). The level of smartness of each field is the result of effectiveness (a smart city offers value to its citizens), innovation, and environmental considerations.

The development of new technologies, including 5G, AI, cloud, and edge computing, accelerates the evolution of smart cities. In March 2021, SaskPower initiated its pilot program for smart residential meters. The Crown Corporation said the decision to initiate the program comes after the installation and testing of 35,000 commercial and industrial smart meters. The smart meters started rolling out in May 2021 to residential customers in communities experiencing higher-than-normal power outages (Mordor Intelligence LLP, 2022). In March 2021, Toyota began building "the city of the future" powered by robots and artificial intelligence on a 175-acre site in Japan. The "Woven City," which will be built at the base of Mount Fuji, will house up to 2,000 staff and families from the company alongside robots. Citizens of "Woven City" will live in smart homes with a range of integrated robotics systems, including sensor-based artificial intelligence to monitor health. Toyota focused on its self-driving vehicle, the e-Palette, to make up most of Woven City's transport infrastructure (Mordor Intelligence LLP, 2022).

In March 2021, Iota Communications, Inc. declared an association with The Stone House Group, LLC, a Bethlehem, PA-based facility consulting firm. They promised to offer high-value and smart building services to K-12, school, and university markets throughout the United States of America. Iota COMM's Bright AI wireless connectivity and data analytics platform brings indoor air quality and energy management data monitoring and analysis to Stone House's customer base, including hundreds of private and public schools and universities. "AI software desire to improve analytics, teaching, customer service, and student success" (Mordor Intelligence LLP, 2022).

The Indian government has also planned to give IoT a push. The Indian Government has prepared an INR 7,000-crore fund allocation to create 100 smart cities powered by IoT applications to control traffic, use water and power efficiently, and collect data using IoT sensors for healthcare (Mordor Intelligence LLP, 2022). The Korea Water Resources Corp (K-Water) has developed smart water management technologies that control Korea's infrastructure. In South Korea, fresh water is found in 3% of the South Korean territory. It represents under 100,000 square kilometers (Mordor Intelligence

LLP, 2022). In September 2021, Tata Consultancy Services (TCS) was selected by Transport for London (TfL) to design, implement and operate a new smart mobility system. In February 2021, Sri Lankan Telecom produced SD-WAN services for its enterprise and government customers in partnership with Cisco and Millenium ITESP to develop digitization nationwide (Mordor Intelligence LLP, 2022).

According to a research made by MarketsandMarkets (2022), the major vendors in the smart cities market are Cisco - US, IBM - US, Siemens – Germany, Microsoft - US, Hitachi - Japan, Bright Cities - Brazil, Maydtech - Mexico, Zencity and IXDen - Israel, Schneider Electric - France, Huawei - China, Intel - US, NEC - Japan, ABB -Switzerland, Ericsson - Sweden, Oracle - US, Fujitsu - Japan, Honeywell - US, Signify - Netherlands, Kapsch - Austria, Motorola - US, Accenture - Ireland, Vodafone - UK, AWS - US, Thales - France, Google - US, TCS - India, AT&T - US, Nokia - Finland, Samsung - South Korea, SAP - Germany, TomTom - Netherlands, AppyWay - UK, Ketos - US, Gaia - India, TaKaDu - Israel, FlamencoTech - India, XENIUS - India.

Methodological section

The study is theoretical and relies on a literature review relating to the COVID-19 pandemic and smart cities. The documentation's analysis aims to identify the impact of the SARS-CoV-2 pandemic on the development of smart cities, to lead specialists to identify new opportunities for smart cities' value creation, to foster knowledge, and to share it.

The research questions are as follows:
How did smart cities manage the COVID-19 pandemic?
How were COVID-19 non-pharmaceutical interventions implemented in smart cities?
What impact did COVID-19 have on the smart cities development process?

The paper focuses on an exploratory study and analysis without setting a systematic literature review. A non-systematic literature review refers to an informative, in lieu rather than all-encompassing, review of the present literature on smart cities. It is based on a knowledgeable selection of the latest, high-quality papers. In the paper, the authors present interesting references and information found in selected articles on the internet and social media, intending to present an academic and practical perspective. This method was chosen to better understand the current state of smart cities during the pandemic and offer support-evidence for the decision-making process of the specialists (Moher et al., 2015). The contributions are emphasized by the literature on smart cities worldwide, COVID-19 non-pharmaceutical interventions on smart cities, and COVID-19's impact on smart city development. The selected contributions are interpreted in a narrative synthesis to elucidate new perspectives and advance theoretical frameworks on emerging issues (Denyer & Tranfield, 2006; Dixon-Woods et al., 2004).

Results and discussion

COVID-19 non-pharmaceutical interventions in smart cities

Non-pharmaceutical measurements in smart cities were used worldwide in different associations and of varying levels of stringency. These interventions refer to wearing masks, restrictions on, or closing, institutions such as schools or businesses,

international border controls, international trade, tests, isolation measures, ventilation measures, and cleaning hands or surfaces. Measurements such as reducing contact between people through institution closures and staying at home contributed to a reduction of around 70% of the COVID-19 transmission in the population during the 2020 spring pandemic period (Young et al., 2021). The mask-wearing contributed to an added 7% reduction overall and up to a 20% reduction among 65+ year-olds in April 2020 (Young et al., 2021). These findings suggest that wearing masks reduces COVID-19 transmission, but only in relation to social distancing measures. The implemented non-pharmaceutical interventions have slowed the spread of infectious diseases. Worldwide, since 2020, fewer cases of flu, bronchiolitis, gastroenteritis, and other diseases have been registered compared to pre-pandemic times (Oh et al., 2022). Measures regarding regular testing of individuals regardless of symptoms and symptom-based testing were successfully implemented.

Technology solutions were adopted in smart cities to handle the pandemic. The most representatives are illustrated in Figure 1.

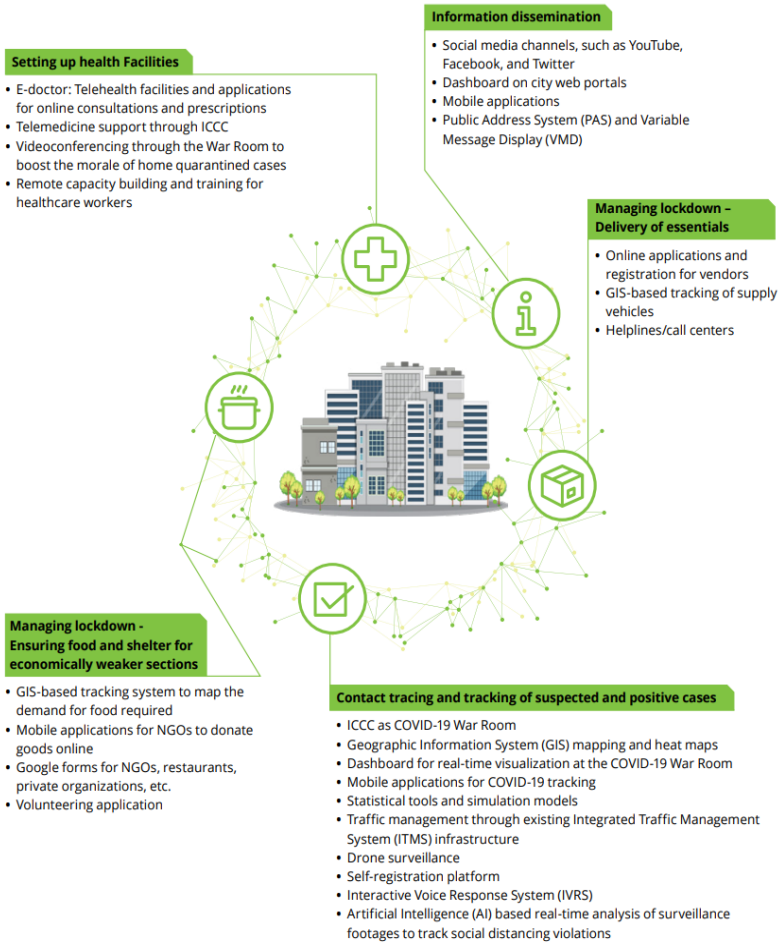

Figure 1. Technology solutions
(Source: Smart City in India, facing COVID-19 response using smart technology and data governance solutions)

According to Regmi and Lwin (2021), there are three enablers and four themes regarding the barriers to control or reduce the transmission of COVID-19. The enablers regard the positive impact of social distance measures, effective public health interventions, and positive changes in people's behavior. The barriers refer to fears and concerns about the virus; the role of mass media; physical impacts, psychological crashes; ethnicity, gender, age, and the COVID-19 pandemic.

The non-pharmaceutical interventions were avoiding crowds, border restrictions, isolation, and working from home to reduce the effective reproduction number of SARS-CoV-2 (Cowling et al., 2020; Pan et al., 2020; Rios-González, 2020; Roy et al., 2020; Al-Hanawi et al., 2020; Li et al., 2020; Wu et al., 2020; Alobuia et al., 2020; Feng et al., 2020; Shorey et al., 2020; Sikkema et al., 2020; Rugarabamu et al., 2020; Grannell et al., 2020; Moorthy & Sankar, 2020; Solerte et al., 2020; Vally et al., 2020). The factors associated with the success of non-pharmaceutical interventions involved governmental measures for social distance and isolation by avoiding crowds, closure of public places, hand hygiene, and individuals' adherence to country-specific mitigation measures (Regmi & Lwin, 2021; Smith et al., 2020; Jing et al., 2020; Islam et al., 2020). Some studies demonstrated that public health interventions involving personal protective equipment (facemasks, eye protection) have been successful as the virus spreads through multiple ways (e.g., touching, sneezing) (Regmi & Lwin, 2021). Other studies believed that part of the success of COVID-19 transmission was changing people's behavior to comply with government actions (Atchison et al., 2020; Rugarabamu et al., 2020).

Fears and concerns about the virus refer to the weak infrastructure, under-resourced health system, inadequate social practices, and widespread illiteracy (Mohamed et al., 2021). Studies reveal that rumors on social measures, electronic and print media about isolation/self-quarantine, and restriction of travel (curfew) were associated with negative impacts on mental health. Consequently, people become stressed, restless, worried, lose social interaction, have difficulties coping, and feel emotionally exhausted (Roy et al., 2020; Regmi & Lwin, 2021). Parents had different types of emotional problems. Some parents experienced symptoms of anxiety (6.6%). Some parents presented depression (21.7%) (Wang, 2021). Studies found that COVID-19 was associated with people from populations in lower socio-economic entities, with exposure risks, employment in a lower category, comorbidities, and old age inhabitants of non-smart cities (Geldsetzer et al., 2020; Wang et al., 2020; Wolf et al., 2020; Wu et al., 2020).

COVID-19 impact on smart cities development

Before COVID-19, the development of smart cities by offering a better lifestyle to the population was a priority. Due to taxation, lower revenue collection at local budgets, workforce, and prolonged lockdown, the development of smart cities was compromised. Except for the investments in medical technology, the development of other projects in smart cities was delayed, e.g., new highways, smart sports equipment, smart city-led lighting systems, smart educational organizations, smart traffic management, new parks, etc. (Gade & Aithal, 2021). SARS-COV-2 has slowed down or even stopped the growth of many countries and smart cities due to forced lockdowns and increased expenses to handle the pandemic. Even though the workforce was reduced, and tax revenues were decreased, many governments, NGOs, WHO, and other

private organizations are developing technology-based solutions such as Cloud Computing, Cyber Security, IoT, Big Data, Data Analytics, and Digital Twins to combat the impact due to COVID-19 pandemic by monitoring the health, safety, and living standard of the population (Shukla, 2020).

Due to their infrastructure (e-governance, telemedicine, GIS-enabled monitoring systems, mobile apps, etc.), smart cities are helping governments handle the COVID-19 pandemic (Yusra Amir, 2021; Zhang, 2020). The social and economic disruption due to the pandemic situation has affected technologies. For example, IoT sensors are increasingly demanded in operating smart infrastructure and buildings because of their support in outlying the remote data-driven process to present accurate monitoring and operational scenarios (Gade & Aithal, 2021, p. 199). According to Gartner Report-Market Trends, IoT has a determinant role in smart cities due to the demand for securely connected buildings, collection taxes through contactless technology, city asset tracking, smart metering living, outdoor surveillance, etc. In post-COVID-19 smart cities, technologies correlated with artificial intelligence can make possible predictive modeling techniques, which can allow smart cities to offer safety, security, and effective implementation of policies, helpful in handling any pandemic situations (Gade & Aithal, 2021, p.199). During the COVID-19 pandemic, cities such as Singapore, Seoul, and Hong Kong managed the pandemic effectively because of their immediate actions in deploying smart technologies (Gade & Aithal, 2021). The COVID-19 pandemic helped the development of smart health monitoring, virtual doctors, hygiene assets, etc.

Smart cities have different roles in each pandemic stage: precrisis, during, and post-crisis. Resilience represents an essential element used in smart city planning to assess growth and prevent unpredictable environments by absorbing shocks and making changes to recovery (Megahed & Abdel-Kader, 2022). The development goals focus on a sustainable future and consider smart cities critical players in developing urbanization and resilience. These smart and resilient entities require proficiencies during the stages of the pandemic, such as preparedness (pre-disaster), response (in-disaster), recovery (post-disaster), and adaptation (new normal) (Megahed & Abdel-Kader, 2022).

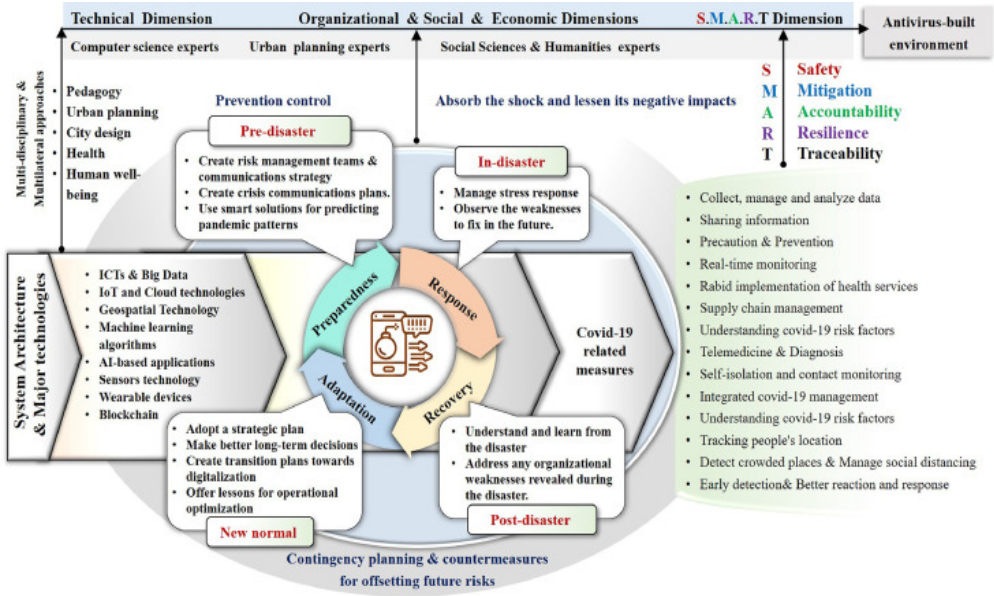

Figure 2. A holistic framework of smart city technologies and implementation to avoid future crises.
(Source: Megahed N.A. & Abdel-Kader R., 2022, p.10)

The preparedness stage explains the procedures implemented before the pandemic that help the overall system response. The response stage refers to all the procedures taken during the pandemic. The recovery stage focuses on reverting to the normal pre-disaster phase. The adaptation stage refers to the process of recoverability and prevention of a new crisis (Megahed & Abdel-Kader, 2022). Maione and Loia (2021) developed the SMART acronym for safety, mitigation, accountability, resilience, and traceability. According to Megahed and Abdel-Kader's (2022) framework, there are five governing dimensions. The first one is the technical dimension. The second one is the organizational dimension, which focuses on the capability of organizations to prepare for, respond to, recover from, and adapt to the crisis. The third one represents the social dimension, which refers to reducing the negative effects of the pandemic. The fourth dimension is based on the economic dimension. The fifth dimension represents the smart dimension with COVID-19-related measures to control risk components (Megahed & Abdel-Kader, 2022). The multidimensional perspectives present the smart city as a cultural, political, and social structure.

Conclusions

A classic city represents a system with a history and a set of social elements. For a city to develop, all its elements must work together by utilizing all the available resources. Smart cities are a modern paradigm with a comprehensive vision. The "smartness" of a city refers to its ability to use all its resources and dynamic capabilities to achieve its proposed objectives efficiently. The key factors in developing the smart cities market include the growth of urbanization, the demand for fast transport, public safety, a healthy environment, and efficient energy consumption. The need for smart cities is increasing due to the increase in urban population. In addition, cities should include

smart technologies to combat future challenges. Smart cities represent the key to long-term sustainability.

Over the past few years, COVID-19 has strongly impacted economies, governments, and the entire society. While cities in developed countries utilize advanced technology, those in developing countries are still working to gain the benefits of digital transformation. For example, many cities were forced to accept new e-governmental and e-health services due to lockdowns and social distancing rules. The COVID-19 pandemic encouraged smart cities to include resilient thinking in their strategies. The COVID-19 pandemic has demonstrated the importance of digitalization. This research found that non-pharmaceutical interventions and personal hygiene and environmental sanitation were efficient in smart cities. Management of confirmed cases by isolating (physical distance) and quarantine recommendations (10–14 days) for close contact with a case represent the essential measures of COVID-19 control. New strategies should be taken to secure smart city data and infrastructure access and management. Smart cities should develop in an organized mode with explicit planning and analysis. They will develop an "antivirus-built environment" against future crises and pandemics in this context.

City management should focus on proactive strategies to gain their citizens' trust and present them with the benefits of the new technology. The use of data and different technologies to respond to the pandemic demonstrates the need to balance personal privacy and public interest. With increasing data collection and developing technology (sensors, cameras, audio systems, etc.), policymakers should create strategies that combat public surveillance fears. Smart cities need very strong security policies because cyber criminals and other malicious actors will try to intervene in various activities. These should represent critical elements of any smart city strategy. Citizens, the public, and private sectors should think forward and invest in smart cities that respond to citizens' needs, offer security, privacy, and respect fundamental rights.

This research emphasizes the importance of smart cities for countries and the synergetic involvement of citizens, companies, and governments in the pandemic context. The present study discusses the various aspects that correlate smart cities and COVID-19. The results demonstrate the importance of technology (open data, data sharing), innovative thinking, the collaboration between public and private stakeholders, and citizens' participation in developing smart cities. Some smart cities adapted their advanced technology to efficiently respond to the COVID-19 pandemic, while others presented a slow reaction against it. Smart city projects involve collective learning processes and innovation for a long-term horizon for urban growth. This paper has some limitations. This study presents only a theoretical framework of analysis to address the pathway leading to smart cities in the context of COVID-19. Further research perspectives and investigations will consider how smart cities will develop after the present pandemic and the factors and barriers to their evolution in a specific context.

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