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Solutions to Manage Smart Cities' Risks in Times of Pandemic Crisis

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Abstract: The purpose of this paper was to investigate technologies, methods, and approaches that can be used to effectively manage smart city risks in the context of the COVID-19 pandemic. The paper was based on a review of specialized literature sources and expert statements on smart cities in times of crisis, specifically during COVID-19. A systematic literature review served as the research's methodological foundation; this was supplemented by conceptual data analysis techniques and a modeling method. Our initial search yielded 234 research articles, 38 of which met our inclusion criteria and were included in the review. A further 32 studies fell outside of the criteria for supporting smart cities' crisis management. The main findings showed that technologies can respond quickly to pandemic crisis risks while also ensuring the availability of urban functionality and that there are numerous risks in implementing technologies to achieve effective management. The main risks were privacy concerns, social inclusion, political bias, misinformation and fake news, and technical difficulties with education and distance employment. The practical significance of the paper lay in proposing a model based on specific technologies and policies aimed at effective risk management in the days of COVID-19.

Keywords: smart cities; risk management; technologies; COVID-19

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1. Introduction

In recent years, the pandemic has put major cities around the world to the test, with many of them experiencing significant destructive shocks over time that have resulted in a radical change in people's normal lives in terms of access to basic services and urban functions. Creating a crisis-recovery risk-management plan that includes digitalization initiatives can be an effective tool for dealing with crisis risks, ensuring people's standard of living and well-being, and ensuring normal access to key public services and processes.

Today, life in major cities around the world is fraught with uncertainty and complexity. The pandemic situation has contributed to the visible highlighting of these issues, which have primarily impacted citizens' quality of life and well-being. In addition to the daily risks of earthquakes and accidents, the result has been significant infrastructure damage and numerous inconveniences for residents (Henkey 2018). This necessitates prompt and decisive action to reduce citizen risks and vulnerabilities as well as infrastructure damage (March et al. 2017). As a result, smart city risk management is becoming a major task for governing bodies.

The modern smart city was founded on three pillars: technology, residents, and institutions (Hassankhani et al. 2021). Based on the technology-implementation principle, several technological tools can be directed to them in tandem with the involvement of residents through key institutions. Such initiatives may include targeted training, population mobilization, and anti-crisis action planning, but no established conventional model for effective urban risk management during a crisis exists.

Practical training is regarded as an effective mechanism because it provides personnel with specific skills for dealing with crises and forms the perceived need for a sustainable urban environment. Thus, achieving a high level of risk management is thought to be the result of crises and disruptions, as well as the subsequent planning and deployment of capabilities to restore and increase resilience, on the one hand; and opportunities to adapt and transition to stability and resilience on the other (Sharifi 2020). This also leads to the use of technologies to improve response capacity and achieve a high level of risk management as a useful approach against risks and vulnerabilities in conjunction with specialized training.

Many empirical studies (Wang et al. 2021; Maione and Loia 2021; Sharifi et al. 2021a; Troisi et al. 2022) emphasized the importance of smart city technologies and demonstrated their widespread use for effective risk management during crises. The emergence of the COVID-19 pandemic highlighted the need to implement technologies to mitigate crisis risks and normalize the situation. A major issue in this direction is that the governing institutions have differing perspectives on which technologies, approaches, and tools to employ, thereby resulting in limited options and opportunities for intervention. In this situation, open governance in modern smart cities can involve more people to reach the appropriate decision.

Based on our research, several major solutions for improving the risk management effectiveness of smart cities were identified, including increased social engagement of residents, implementing appropriate technologies, ensuring physical and mental health, and focusing on education and engagement (Robeyns 2017; Ribeiro and Gonçalves 2019). Adequate action in these areas is expected to improve the situation in smart cities during the COVID-19 pandemic, which will allow them to respond quickly and adequately to future crises. All of the solutions mentioned above can be combined into a comprehensive model that takes into account smart city specifics and provides guidelines for an effective counter.

2. Materials and Methods

A systematic literature review was used as a methodological basis in this study and content analysis via text mining, and conceptual data analysis techniques were developed. In this systematic review, we identified studies that describe the management-related knowledge of COVID-19 from a smart cities perspective to provide an overview of the major issues and propose solutions for effective risk management in the form of a comprehensive model.

2.1. Method Description

Systematic reviews are different from traditional literature reviews in that they are formally scheduled and thoughtfully carried out. They are designed for self-replication and thus have a different type of scientific value than standard literature reviews. The main research method steps used in this study were adapted from (Tranfield et al. 2003) three-step methodology, which included preparing the study, performing the study, and disclosing and distributing the results. These steps exactly reflected the sequence of activities in carrying out our research.

2.2. Inclusion Criteria

A complex of keywords and search criteria for scientific developments was developed to implement the first stage. These keywords included risks, smart city risk management, COVID-19 measures and models, and COVID-19 risk mitigation technologies. The keywords for the inclusion criteria were selected according to the main objectives of the study, which were related specifically to the risks for smart cities during the pandemic and the use of technology for effective risk management. To achieve the study's objectives, risk management methods and approaches used in smart cities to increase resilience during the

crises in Europe, the United States, and the Middle East were investigated. We chose these areas because the most developed smart cities were located there.

2.3. Literature Search

Around December 2019 and February 2021, we searched scientific studies to provide relevance to COVID-19 as well as relevance to the study objective. Any articles published before 1 December 2019 were excluded during the initial screening stage. The titles of the studies were independently reviewed in order to eliminate those that did not meet our inclusion criteria. Additional studies were added to describe the foundation of smart cities. Because they were unrelated to the COVID-19 spread, these studies included older data. Some studies of smart cities' crisis management outside the period of 2019–2021 were added to our research to achieve the main goals.

3. Results

Through title and abstract screening, we identified 38 smart city risk management and modeling studies on the COVID-19 outbreak in 2019–2021 from the initial search of 234 articles. The following 32 studies were conducted outside of the criteria period:

- 20 for smart cities fundamentals;
- 12 supplementing COVID-19/smart city risk management.

The detailed selection process is illustrated in Figure 1.

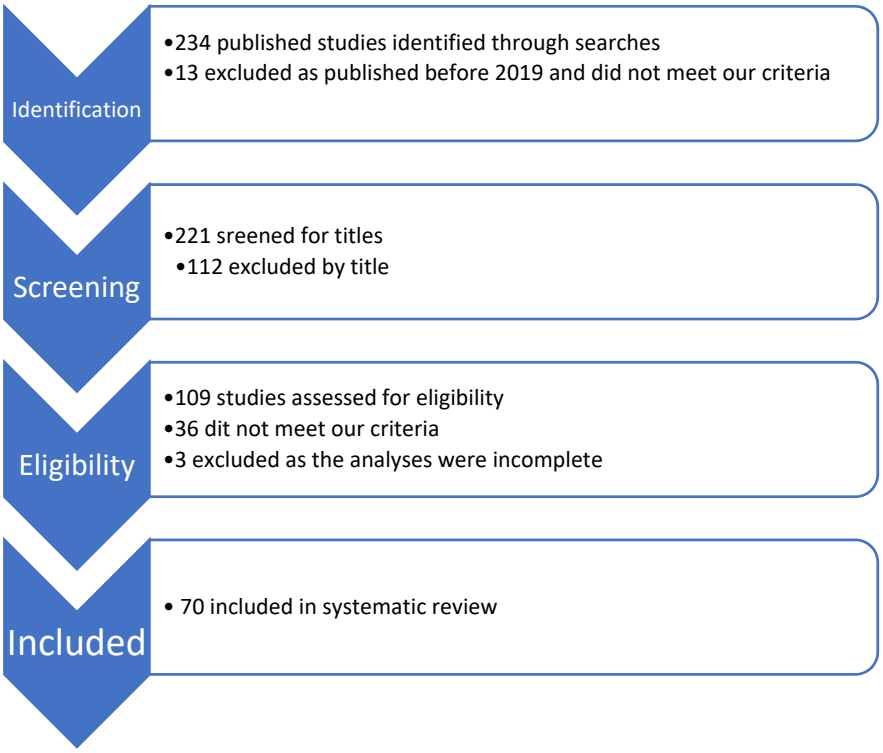

Figure 1. The study's selection process.

3.1. Smart City Basis

Because the research was focused on smart cities, it was necessary to define which cities are considered smart. The term "smart city" refers to a digital city with many soft assets and soft components apart from the digital part and is regarded as a concept with no unambiguous definition. Experts in this field agree that a smart city should not be thought of as a place where many technologies are concentrated. Current interpretations of a smart city emphasize numerous components of city operation with a particular focus on the contributions of transportation and communication facilities, communication

technology, electronic content, and entertainment arts; and based on cultural initiatives to enhance political and socioeconomic efficiency (Hollands 2008) and empower the community through innovative communications channels with the government (Lombardi et al. 2012). Komninos (2002) proposed a broad definition that characterized the smart city as a location with a high level of educational and innovativeness, creativity, research and advancement organizations, academic institutions, Internet connectivity, communication technology, and operating efficiency. We can summarize that components of a smart city include territory, technology, citizens, and governance.

The technological component is viewed as a tool for achieving the goal of the smart city concept, which is to create a comfortable urban environment (Sikora-Fernandez and Stawasz 2016). Even though technology is the main driving force of a smart city, a smart city will not prosper or be stable until there is genuine involvement and a desire to work together by government entities and citizens. We can note that citizens are important components that should not be overlooked. The open network of smart devices serves as the foundation of the smart city, allowing all users and citizens to demand or create services that are most important and valuable to them (Baron and Kuźnik 2017). The authors defined a smart city in the context of this study as a system that connects and automates various technologies aimed at providing basic services to society, efficient resource management, and environmental protection.

Smart cities deliver connected solutions to the public by utilizing a variety of software, user interfaces, and communication networks, as well as the Internet of Things concept (IoT). The goal is to create a system of interconnected equipment capable of communicating and transferring information. Vehicles, household appliances, and street sensors are all examples of this. The information gathered by these gadgets is saved in the cloud or in data centers in order to enhance the effectiveness of the both public and private sectors, as well as to provide economic benefits and improvements to citizens' lives. A large variety of options are used in this direction, first from surroundings to the public sector and from individuals' services to digital services. (UNCLG 2020). Individual solutions do not share infrastructure or generated data even if the same infrastructure and data are used and included in multiple services. Services must be classified based on their characteristics in order to understand both their technological and governance requirements. The technological aspects of smart city services are primarily concerned with customer satisfaction and other system specifications that are mainly connected to facilities and service development. The following are key features shared by every smart city's solutions in terms of technology and quality of service parameters:

- User count;
- Device count;
- Information quantity;
- Delay awareness;
- On-the-spot applications;
- Charging;
- Extensibility;
- System integration and flexibility.

During the COVID-19 pandemic, service quality has suffered significantly, thereby raising the risk of decreased consumption and trust in the services provided. Maintaining the quality of services provided in smart cities is a critical point that must be considered when developing a model for effective risk management during a crisis.

Regulatory features relate to laws and regulations related to smart city services. The most crucial aspects of a service were correlated to the features below (Weber and Žarko 2019):

- Legal fumbled snap;
- Infrastructure-functioning consistency;
- Safeguarding private information;
- Confidentiality;
- Provider swaps;

- Roaming;
- Interoperability and free access to data and services.

The concept of smart cities is to continuously monitor key infrastructure elements such as roads, bridges, tunnels, railways, subways, airports, seaports, communication systems, water supply, electricity, and specific buildings in order to optimize resource allocation and ensure safety. So, the distinguishing characteristics for a city to be classified as a smart area are as follows (Shichiyakh et al. 2016):

- Availability of ICT infrastructure—the secure and protected ICT infrastructure of the latest generation is of paramount importance for the successful provision of new services in smart cities and to ensure readiness for the provision of new services in the future;
- Existence of a built and integrated management system—the many systems of a smart city can work together via various integration mechanisms (Lane and Epstein 2013);
- Availability of smart users—technologies are a means to ensure the functioning of the smart city, but they are useless in the absence of competent users who know how to interact with the services provided.

Another point of view argued that cities can be defined as smart if they have the following elements (Sikora-Fernandez and Stawasz 2016):

- Smart financial system—urban areas ought to have an increased performance predicated on the utilization and mixture of knowledge-based means of production, an innovative climate, and a flexible labor market. The economy should be distinguished by the use of creative technologies and adaptability to changing circumstances;
- Smart mobility—the city grows into a massive system of links among all of its assets;
- Intelligent surroundings—a smart city enhances its power usage through the use of renewable resources as well as other implications, seeks to minimize environmental pollution, and outposts its recycling programs on the principles of responsible development. Sustainability initiatives necessitate a significant amount of environmental learning as well;
- Intelligent citizens—an educational community;
- Smart residing—sociable atmosphere, particularly through the stipulation of broad public service accessibility;
- Smart governance—cooperation of local authorities and other users of the city;
- Viewed as a functioning system, smart cities use a network of interconnected gadgets as well as other systems to enhance the standard of living and empower productivity expansion in four steps (Twi 2018). They are:
    - Gathering—intelligent devices retrieve information directly;
    - Analysis—the information is analyzed to get an idea of the work of city services and operations;
    - Connection—information results obtained are conveyed to the government;
    - Do—activities are implemented to enhance processes, financial services, and citizens' value in urban life.

3.2. COVID-19 Impact

The negative consequences of COVID-19 spread in smart cities necessitate a study of citizens' attitudes and perceptions regarding the measures implemented followed by an assessment of the impact of the pandemic on people's lives and the level of their dissatisfaction and stress (Sheth et al. 2020; Abusaada and Elshater 2020). This is necessary because citizen perceptions and attitudes are regarded as key indicators in the implementation of technological solutions in smart cities. This leads to the concept of technological anxiety, which is defined as a set of emotions associated with the uncertainty of acquiring knowledge for the use and subsequent use of certain technologies. Risks are primarily associated with negative outcomes such as data loss or improper exploitation caused by a lack of knowledge and skills as well as the confidence in one's ability to use certain technologies.

This insecurity is frequently caused by emotional states, psychological factors, addiction fears, and privacy concerns.

Other research focused on technological risks and opportunities to increase resilience by assessing the individual infrastructures on which COVID-19 has had a negative impact (Zimmerman et al. 2017; Vermiglio et al. 2020). Bloomfield et al. (2017) presented a study that demonstrated the concept of creating synergies between various infrastructures and the services they provide for effective risk management and mitigating the effects of COVID-19. As a result, a methodology for a risk-prevention plan was developed with estimates for all implemented sustainability measures.

Another study (Fotouhi et al. 2017) focused on creating a comprehensive risk-management model through the development of a modeling and simulation framework. Tweneboah-Koduah and Buchanan (2018) proposed a similar model and extended it with mathematical methods to model critical infrastructure interdependence.

Other authors' research focused on public participation as a mechanism for mitigating the effects of crisis risks. According to these authors, technology can increase social engagement and thus more effectively counter crises. The technologies themselves are chosen with the goal of increasing transparency and thus strengthening trust between citizens and governing institutions. In this vein, social media has been widely used in recent years to increase citizen activity as an innovative risk-management method. Cheng et al. (2015) focused their research on potential risk management tools based on social media used either actively or passively.

Other authors concentrated on the most popular social networks. Kankanamge et al. (2020), for example, argued that posting images from key public institutions on Facebook and Twitter can significantly increase people's attention in times of crisis and encourage greater involvement in public affairs and activities (Finau et al. 2018). Despite the risks of inaccuracies in messages transmitted via posts, in the networks themselves there are signaling mechanisms that administrators can use to make corrections (Chao et al. 2020). Risks associated with inaccurate information cannot be completely eliminated, so recommendations for locating authentic and reliable sources are issued. In this regard, a study by Boas et al. (2020) demonstrated that while citizens in certain crises primarily obtain information from social networks and official channels of the governing institutions, an additional check is performed for the security and accuracy of the information on the institutions' official pages. Linders (2012) distinguished three types of media platform relationships: between citizens, between citizens and government, and between government and citizens. The author identified citizen communication as a critical factor in improving well-being. Residents become more informed and attentive in times of crisis through social networks, so the information itself can encourage timely preparation and subsequent adequate response (Rajput et al. 2020).

A crisis can have a serious long-term impact on the education system depending on the rate of development. In just one year, COVID-19 had an impact on over 1.6 billion trainees (Hassankhani et al. 2021). This also focused on the risk sustainability and capability of smart cities to transform traditional education into distance education by providing educational services to all individuals without regard to social or geographical limitations (Van Wyk et al. 2020). In general, many people believe that online learning is the ideal solution to the challenges that COVID-19 poses to education. While online learning may appear to be a good way to protect the community from COVID-19 at first glance, it is causing serious physical and emotional problems among students (Petropulos 2021). The main disadvantage of distance learning is fraud in both class attendance and the administration of exams and control tasks. Additional negative effects include a reduction in actual learning time due to the inability to provide educational materials in the physical environment of the classroom, endangering learners' mental/emotional health due to a lack of social contacts and the requirement to connect only through a communication device, and a significant decline in physical activity among students.

3.3. Measures Implementation Challenges

This paper investigated how various measures were used to respond to the COVID-19 pandemic issues in order to propose new risk-management processes for smart cities. However, implementing measures is accompanied by many challenges and obstacles:

- Priority must be given to confidentiality, trust, and human rights risks. The effective fight against the COVID-19 pandemic necessitates the use of a variety of tracking applications, sensors, and other real-time data collection devices that severely infringe on residents' privacy. Furthermore, technology institutions that provide digital technologies for the city and that access residents have full access to each individual's information, which poses privacy risks. These challenges necessitate careful consideration and the application of appropriate technologies in order to eliminate citizens' risks and concerns during times of crisis (Tedeschi 2020);
- Digital inequality (UNCLG 2020). Unequal access to digital resources is problematic from two perspectives: access to technology and the risk of irrational use after access (Watts 2020). During the COVID-19 pandemic in particular, certain age groups may be less knowledgeable and skilled regarding various technologies and devices, and temporary residents may not have access to the smart city's services at all (Seifert 2020). As a result, ensuring access for all residents and increasing social inclusion has become a critical risk issue for both digital service institutions and governing institutions (Levenda et al. 2020);
- Turning digitalization into an undemocratic process in which governments misuse technology (Vanolo 2014). There is also the risk of intentional or unintentional dissemination of incorrect information through specific channels, which, as previously stated, can be corrected by administrators of relevant digital resources. However, they may be influenced by various large corporations using their reputation and putting pressure on them to misrepresent false data and facts, thereby violating democratic principles;
- Complexity of data-processing actions due to COVID-19's current data sources' specific algorithms. This can lead to misinterpretation, incorrect understanding, and, as a result, incorrect outcomes, thereby putting urban governance at risk of less transparency and accountability (Matheus et al. 2020). At the same time, a city government's high-tech information process costs for the dissemination and use of technologically oriented tools (Papadopoulos et al. 2020) against COVID-19 are quite high;
- Difficulties with educational services. In the case of mass training institutions, foreign individuals with varying understandings and abilities are trained, which brings to light the risk of digital access inequality when conducting distance learning. Numerous studies conducted prior to the days of COVID-19 demonstrated that digital learning was ineffective due to the inability to account for learner differences. This can result in a lag in certain individuals and, as a result, a situation of educational inequality (Murat and Bonacini 2020). It should also be noted that some training courses necessitate physical presence and an increased level of social contact, which is impossible to achieve through distance learning;
- Remote employment is also at risk during COVID-19. Although remote work allows for a more flexible schedule, it still significantly blurs the lines between personal and professional life. According to Hu's (2020) research, remote employment can significantly boost productivity. However, there is a risk of serious negative consequences in the long run due to the accumulation of schedules and the reductions in free time (Okubo 2020). Security and stability risks in remote employment, as well as access to organizational data, should be supplemented;
- Vaccination issues. With the spread of the 2019 coronavirus (COVID-19), vaccination is becoming increasingly important around the world (Singh et al. 2022). Vaccines are widely regarded as the most effective means of reducing the number of infected people and eventually eliminating the infection. Significant issues with this direction include the impossibility of vaccinating a large portion of the population, which is the

case in China (Statista 2022); and, perhaps more importantly, insufficient quantities of necessary vaccines. This highlights the importance of optimizing production and ensuring adequate vaccine supplies. The Internet of Things concept is critical in a smart city for manufacturing vaccines with wearable sensors. Traditional manufacturers rely on trusted third parties, which can serve as a single point of failure. Due to demand response data in advanced manufacturing, access control, big data, and scalability are also challenging issues in existing systems. To address these issues, a P2P smart-contract-based smart architecture of a smart city for vaccine production with three layers (including connection, conversion, and a smart cloud layer) was developed and proposed (Singh et al. 2022). The goal was to provide security and privacy while maintaining adequate access control. Contracts such as contract registration, contract manager, and contract access control are used for secure data communication with distributed access control to produce vaccines.

3.4. Smart Cities' Risk-Management Indicators

The research presented examined various aspects of risk management in smart cities, but to determine the level of sustainability, indicators that monitor risk management effectiveness also had to be considered. As the goal of all smart-solution initiatives is to improve the lives of residents in order to be defined as successful and sustainable, the approaches must reduce pollution risks, increase access to social services, and more. This necessitates evaluation of the initiatives that have been implemented in order to obtain feedback on their effectiveness. This implies that cities' intelligence must be measured using indicators that show how they are dealing with risk challenges.

A city government can employ a diverse set of indicators that differ in terms of measurement, scope, summary data, and main purpose. As a result, selecting a high-quality set of indicators is a difficult task. However, there are widely accepted risk-management pillars that must be considered when evaluating smart city performance. As a result, a classification scheme can be used to select specific indicators for the risk management of smart cities with six main aspects—smart environment, smart living, smart mobility, smart governance, smart people, and smart economy—included. The selection of indicators must take into account the main characteristics related to their correct use. These were presented by Petrova-Antonova and Ilieva (2018):

- Measurability;
- Reliability;
- Relevance;
- Intuition;
- Exclusivity.

Many researchers have reviewed indicators for reduced risks, including several classifications that covered various aspects of mitigation. Figure 2 depicts a model of a generalized scheme developed by Anand et al. (2017) and others that covers a wide range of indicators of smart cities' risk mitigation.

The indicator values were determined by relating them to the six thematic areas; the values typically ranged from 0 to 1 depending on the degree of mitigation achieved. These indicators were used in the conceptual model to assess the degree of risk mitigation achieved.

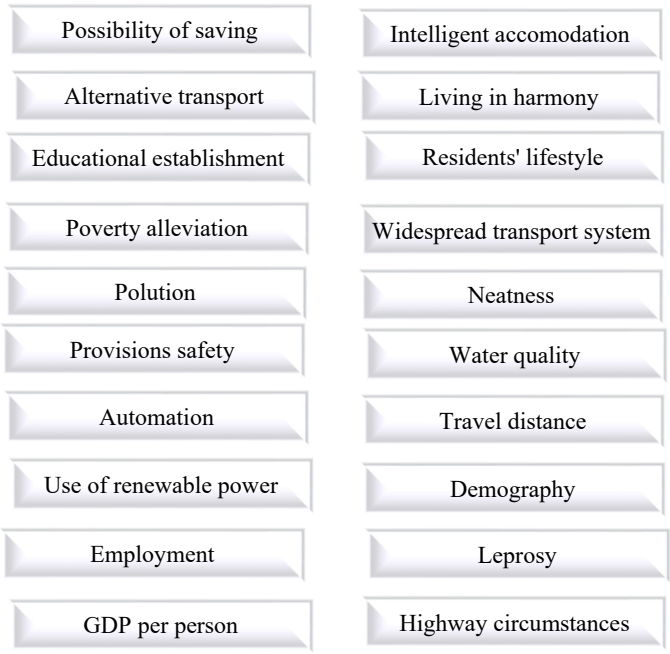

Figure 2. Smart city risk-mitigation indicators adapted via (Anand et al. 2017).

3.5. Estimate Studies

Data from several studies that demonstrated the use of specific technologies and methods by region are presented below to establish the situation regarding smart cities' risk management during crises. These data were required because they were used as the foundation for the risk-management model; developing an effective model necessitated the investigation of the experience and best practices in the most affected areas.

3.5.1. Asian Region

The Asian region is home to the majority of the world's technology giants in terms of turnover and technological innovations as well as the world's leading smart cities, the most notable of which are in China, which draws attention to them. Currently, China is second only to the United States in the provision of artificial intelligence technologies; start-up technology initiatives invested more than 296% of the global average from July 2018 to July 2019 (Perrault et al. 2019). This enormous potential is reflected in the use of various technologies in the fight against COVID-19 and in mitigating pandemic risks. To begin with, it should be noted that China has the most advanced mass surveillance system in the world, which can be used in times of pandemic crisis to obtain real-time data on body temperature and the effectiveness of various regulations such as mask use. When wearing masks, facial recognition becomes a problem because the system's efficiency drops to 30%. In this regard, the developers have proposed an improved version of the system that improves its ability to detect masked faces by 95% (Inn 2020). As a result, the improved facial-recognition system allows for a clear picture of people's movements as well as those who may be infected with COVID-19.

In addition to surveillance systems, robotic systems with artificial intelligence robots equipped with cameras and scanning sensors are widely used in China's smart cities. These robots have been used to assess the health of residents in direct contact with them, which reduces the risk of complications due to the distance between residents and control authorities and also increases efficiency because autonomous robots can scan more than 10 people simultaneously and in a wide range of actions (Inn 2020).

China's successful implementation of the avant-garde in the fight against COVID-19 risks has been recognized by the World Health Organization. An examination of China's experience emphasized that China was the first country to use artificial intelligence on such

a large scale to combat pandemic crisis risks and that that the pandemic would be far more devastating in the absence of such measures.

Singapore, a distinct smart city in the region, suffered significant damage as a result of COVID-19 due to the large number of tourists in early 2020. To effectively counteract this, the government raised public awareness by presenting up-to-date data on COVID-19 using high-value technologies and extensive data analysis. This was supplemented by the allocation of USD 48 billion in earmarked funds, including USD 20 billion in corporate loan capital, property tax cuts and deferrals, cost reductions, and lending incentives (PwC 2020).

3.5.2. Outside Asian Region

Smart cities in Europe are responding to the ongoing COVID-19 pandemic with a variety of risk-management strategies. This includes monitoring traffic in order to collect mass public data as well as increasing the use of public energy data. Smart cities have been primarily focused on improving telecommunications, tracking data, and citizen services during the pandemic. Examples include the MAtchUP platform in Valencia, the Sharing Cities initiative in London, the Replicate system in Florence, and others (SCM 2020). The security of COVID-19 contact-tracing apps is one of the most important and vital aspects identified by the eHealth Network (European Commission 2020). Concerns have been raised about the possibility of a variety of security weaknesses lingering in those online services, which could put a person's sensitive data at risk of being compromised (Pranggono and Arabo 2020). A study conducted by Hatamian and colleagues in 2021 (Hatamian et al. 2021) revealed several critical vulnerabilities. The result was that potentially sensitive information such as usernames, passwords, keys, and so on is stored, which is considered a high burden. Using hard-coded sensitive information, on the other hand, poses a high risk because it allows an intruder to bypass the software's administrator-set authentication. The data may be obtained in this manner by reverse engineering the source code of contact-tracing applications. As a result of obtaining this information, an intruder may obtain more-sensitive data such as medical conditions and GPS tracking information. According to an additional interpretation of the results, 75% of the applications use a desktop version and run a basic SQL statement. Incorrect data in basic SQL statements may result in local SQL injection in the contact-tracing application. In addition, applications typically use an unencrypted SQLite database. This exposes sensitive information to attackers gained who close contact with the smart device or a malware app that has root control over the device (Jain and Shanbhag 2012). Furthermore, a lack of encryption can result in privacy violations and noncompliance with data-protection laws and regulations. Applications may use insecure SSL implementations, thereby resulting in insecure communication and vulnerability to MITM attacks, which undermines the privacy and integrity goal of information security (Jain and Shanbhag 2012).

Many cities in the US region were unprepared for the COVID-19 crisis, which undoubtedly caused significant damage. However, in many cases, such as in Boston, increasing citizens' social engagement and active participation in social processes proved to be a critical factor and a tool for effective risk management during times of crisis (PwC 2020). Several organizations have actively engaged residents in the fight against the pandemic using initiatives such as holding numerous training courses during the crisis, optimizing food supplies by both government and private organizations, and more. As a result, the affected regions will be able to successfully adapt to the growing pandemic while also building a stable urban infrastructure capable of withstanding future challenges.

In March 2020, a Community Fund for COVID-19 was established in New York City (similar to that of Boston) to support efforts to alleviate and recover from the community humanitarian crisis of coronavirus risks. This investment helps partner agencies and social organizations that work with low-income communities by supplying resources and financial assistance. It concentrates on satisfying the urgent needs of New Yorkers via support measures even while functioning to increase family identity and enhance the nonprofit segment (UWNYC 2021).

3.6. COVID-19 Countering Model

As a result of the systematic review, an attempt was made to develop a model for effective smart city risk management that took into account the specifics of the measures in each region and did not contradict the adopted strategies and concepts for smart city development.

The model for mitigating COVID-19 risks presented by PwC (2020) that is widely used by high-tech smart cities such as Boston, Singapore, Helsinki, Vienna, and others served as the foundation; it is presented in Figure 3.

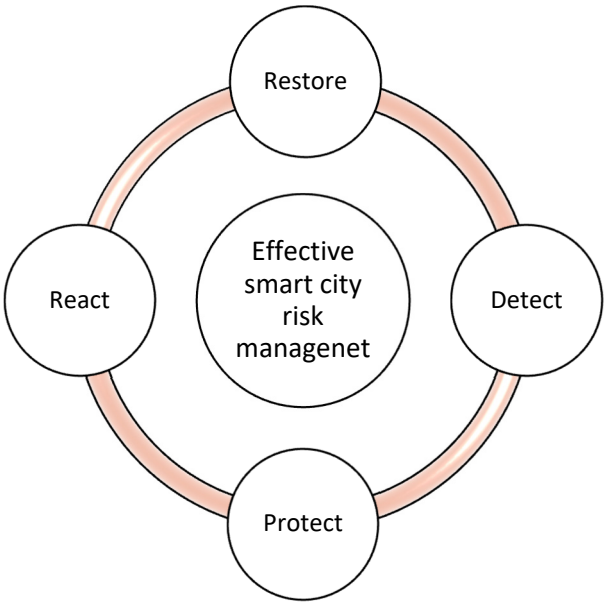

Figure 3. Smart city risk-management model adapted by PwC (2020).

The proposed model suggests four key steps:

- Detect—anticipation of threats through in-depth analysis;
- Protect—strengthening vulnerabilities;
- React—creation of a crisis center for counteraction;
- Restore—identification of key means of functioning at reduced capacity.

The authors' efforts were focused on improving and enhancing the presented model by including more people, activities, and key technologies. The model was reinforced by a focus on four main pillars of risk management in times of crisis such as during COVID-19. The preliminary preparation and creation of an effective stability plan is associated with the first element of an effective model for a high level of management. This includes acting and choosing appropriate technologies before a crisis occurs. An effective plan must be developed in such a way that certain actions are permanent and some are ready to be activated during various waves of the crisis. From a technological standpoint, the plan should include the maintenance of a stable smart urban infrastructure, the implementation of rational city government risk-management procedures, and digital social services and smart technologies to analyze and forecast future risks and events. This could include technologies such as edge computing, blockchains, artificial intelligence, software-defined networking, and big data analytics (Jo et al. 2019).

- The idea behind edge computing is to build networks that will allow urban IoT devices to be supported by the cloud (Wang et al. 2018). The goal of this model is to reduce data-transmission delays between network nodes. If a device cannot connect to a network node, it will temporarily receive data from the cloud to provide continuous services;
- Blockchain technology is a concept for connecting all city systems into a single network while maintaining a high level of security for data stored in interconnected blocks (Nagothu et al. 2018; Mora et al. 2021);
- Artificial intelligence is used in systems and devices for voice and facial recognition, network security against foreign country penetration, authentication device profiling, analyses to optimize the performance of IoT devices in smart cities, and other purposes (Chen et al. 2018);
- A software-defined network is a concept for ensuring network availability and eliminating congestion by prioritizing traffic routing (Abhishek et al. 2016). Software agents set priorities to redistribute network resources as needed and achieve a stable and permanent connection between residents in an emergency;
- The massive amount of data collected by devices in various smart city systems necessitates the implementation of a big data analysis model in urban planning. Rathore et al. (2016) proposed a four-step model for analyzing big data in smart cities to enable the government to make smart decisions that are implemented in real-time.

Following the development of an effective plan, the impact of a risk event should be assumed. Acceptance of an event's effect is linked to the ability to reduce the risk of losing certain system functionality. In this regard, in the context of COVID-19, measures to reduce the risks of virus spread, facilitate communication and data collection, and eliminate channels for the dissemination of fake news are implemented. Effective measures to absorb the effects of the crisis result in a gradual return to precrisis conditions. The use of intelligent solutions and widespread vaccination can hasten the recovery process by providing busy staff with alternate means of ensuring the continuity of core processes and functions.

The final step is to analyze the crisis and use accumulated knowledge and skills to improve the quality of the urban system and increase the capacity to ensure effective risk management in future emergencies. A key activity in this field is measuring the impact of technology implementation through risk-mitigation indicators for the efficiency analysis of invested funds and technologies for risk management in smart cities. This step includes measures such as accelerating digitalization processes (Allam and Jones 2021) and conducting targeted training to optimize smart city processes. A complete view of the authors' enhanced model is presented in Figure 4.

The proposed model was an attempt to present a comprehensive mechanism for effective risk management in smart buildings during a pandemic. There is currently no evaluation of its effectiveness. Its eventual assessment, which should be the subject of future research, can be carried out in the event of future crises.

The benefits of the proposed model primarily include guidelines for dealing with risks during a crisis and ensuring citizens' well-being.

Figure 4. High levels of smart city risk-management model.

4. Discussion

Today, technology is an important tool for dealing with crises. The COVID-19 pandemic has put the entire world at risk, and in times of crisis, smart city technology has demonstrated that it can increase resilience while also ensuring key public functions and people's normal lives. This study drew on a wide range of specialized literature sources and empirical studies to examine the impact of smart urban technologies on risk management and residents' well-being. The technologies themselves are constantly improving and have achieved a high level of smart city risk management via combinations with effective urban planning aimed at strengthening social inclusion and connectivity of residents, transparency of governance processes, improving residents' health, and expanding urban functionality and educational services.

Our findings demonstrated smart cities' ability to respond quickly to pandemic crisis risks while also ensuring the availability of urban functionality (Fan et al. 2021). However, it should be noted that there are numerous risks in implementing technology to achieve effective management. The main ones are privacy concerns, social inclusion, political bias, misinformation and fake news, and technical difficulties with education and distance employment. The listed risks necessitate the development of a strategy for taking targeted measures without significantly interfering with residents' normal lives. This strategy may include:

- Being fully democratic in the use and implementation of technologies;
- Finding effective ways to activate the technically inactive population and direct it to participate in the educational system and social processes;
- Effective telecommunications use to facilitate the continuity of everyday COVID-19 situations;

- Integration of various social media and tracking applications, etc., with the urban system by promoting digitalization processes.

Due to the diversity and specificity of different technologies, attitudes and traditions of different regions, and the degree of digitalization, our study did not provide a comprehensive analysis of the possibilities for effective risk management by smart cities in times of crisis. The goal was to develop and supplement other research aimed at implementing smart solutions in smart cities to ensure good resilience and mitigate major risks during pandemic crises (Sharifi et al. 2021b). The research's dependability stems from a thorough review of numerous specialized and academic sources on the subject of the paper as well as the developed conceptual model for managing risks in smart cities during crises.

The study was conducted under the following constraints:

- The research spanned the years 2019–2021 and did not include the post-pandemic era;
- Risk-management approaches were technologically oriented with no consideration given to internal institutional measures. For example:
- Small populated areas in the composition of smart cities in which there were several peculiarities in the targeting of technologies and measures were not studied.

Many topics could be researched in the future. These include the attitudes and continued use of technologies by consumers from various socio-cultural backgrounds; the type, form, and sources of information they trust; and government actions to eliminate digital inequality. Even as digitally driven urban development has emerged as a new approach for cities with a high level of digital concentration, the digital divide is becoming a major issue when it comes to the objective of making cities accessible and inclusive for all, particularly the most vulnerable. People with disabilities face significant ethical and responsible governance challenges in areas such as digital inclusion and access to key urban services, information, and experiences. Digital-inequality issues can be handled via approaches such as trusted inclusive digital service delivery, responsible use and sharing of data and information, and initiatives for public participation and engagement.

Aging issues should also be noted—older citizens face specific difficulties in getting to the city and are frequently excluded from assets for healthy aging. The smart city ideology aims to bring about technical innovations while also improving urban citizens' quality of life. Technological solutions are a critical part of the smart city and have the potential to enhance older people's autonomy, independence, and well-being. Cities are seen as a hotbed for stimulating technological and social change in the face of accelerated aging and urbanization. Smart cities have the potential to respond to the twin global trends of urbanization and ageing, which are beginning to transform the community and increase issues; possibilities for sustainable and equitable urban environments can be established by delivering digital innovations. To do so, smart cities and urban policies can provide advanced strategies to help an aging population by including critical interventions to satisfy the needs of the elderly while also improving their well-being.

Another future research topic could be the dissemination of technologies and measures to improve the efficiency of small settlements, which are parts of smart cities' administrative power. These are much more vulnerable areas, and proposing and targeting solutions would be a useful risk-management tool.

Smart city open governance and open data are a major topic for new-generation smart cities. Smart governance is directed toward effective cooperative management. From our point of view, the principles of smart city open governance should firstly include smart city inclusiveness—open governance must aim to include everyone, which includes highly vulnerable populations and hard-to-reach groups. The gender ratio must also be a goal in all procedures. The digital divide in societies should always be considered in ICT-enabled open governance. Open governance should also take into account confidentiality—the huge amounts of information accumulated in cities today provide an enormous potential for improved service and management. On the other hand, they endanger personal rights and privacy rights. Open-governance solutions enabled via ICT must respect privacy and incorporate it into their method and process improvements. We must add democratic

accountability, which consists of approaches to open governance that are often ingrained in a legal and formal framework. They do not replace—but rather supplement—the existing democratic processes. It is critical to strike a proper balance between the framework of organizational paradigms and new, open forms of governance. This is especially important when considering which issues remain solely in the hands of elected public officials and why. Open data can be used by governments, organizations, and residents to generate social, institutional, and benefits for society. Many issues must be addressed in order to achieve those benefits, including those regarding organizations, job involvement, use and involvement, legislation, quality of information, and technical problems. The societal challenges moderate the impacts of open data initiatives on the dimensions of smart cities. As a result, smart city governance should have a framework to evaluate the effects to guarantee that the objectives are met.

Because digital technologies have proven to be critical during the time of COVID-19 and are present in nearly all activities, services, and processes in people's daily lives, future research aimed at developing policies and strategies for urban risk management in future crises is required. It can be added that the range of sources used in future research can be expanded to more fully convey the data and circumstances associated with the occurrence of an emergency. Furthermore, the post-pandemic era is an area worthy of future research because recovery from the catastrophic effects of COVID-19 is a process that necessitates extensive attention—both academically and institutionally.

5. Conclusions

Smart solutions and technologies in smart cities are critical tools that have the potential to significantly increase risk management during an emergency or crisis. A stable, smart urban infrastructure is critical to effectively counteracting the devastating effects of the COVID-19 pandemic because it allows for the adequate absorption of the pandemic risk, subsequent implementation of plans, and deployment of models in response to the crisis. This is related to a focus on preventive measures such as effective monitoring, tracking, expanding contactless services and adding new automated services, raising public awareness, and other activities.

The additional deployment of intelligent solutions aimed at supply-chain continuity and technologies to normalize load capacity supports and ensures the smooth operation of processes in various sectors. The aggressive and comprehensive targeting of innovative, effective smart solutions and technologies contributes to long-term adaptation and capacity building in crisis-risk responses, which is complemented by a number of socioeconomic and environmental benefits.

However, the realization of these benefits is contingent upon available funds and management vision for both city development and effective crisis risk mitigation. This demonstrates the desires to attract investments in smart city technologies in order to increase resilience to adverse crises such as the COVID-19 pandemic and effectively eliminate barriers to the implementation of effective risk-management technologies. In this way, smart cities can improve the risk-management model's main pillars of planning, crisis management, recovery, and capacity building, as well as the environmental impact, which is a key priority of smart city initiatives.

Despite the undeniable ability of smart solutions and technologies to improve the efficacy of risk management, achieving this depends on a number of socio-economic and institutional factors such as data confidentiality, ensuring equal access to systems and services, traceability risks, and several legal barriers, all of which can be difficult to overcome. These issues necessitate a more in-depth examination and will be the subject of future research. Nonetheless, smart solutions have the potential to provide opportunities for more effective risk management in future pandemics and similar crises.

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