Towards integration of smart and resilient city: literature review

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Abstract. Smart and resilient cities are on the same path to long-term sustainability and need the creation of an ecosystem that can withstand an increasing number of hazards in the future. One of the primary goals of the smart city movement was to address many issues that have arisen as a result of growing urbanization, including the scarcity of energy, traffic congestion, and pollution. The way urban dwellers live, work, and travel due to more often natural disasters and political issues is changing, and this has an impact on the economy and business models, forming a new trend in urban studies. Smart cities play a critical role in the worldwide fight against Covid-19 in terms of tracking and tracing instances of coronavirus using smart technologies. The integration of smart buildings into a smart city also plays an important role in this scenario, providing advanced infrastructure and greater comfort for their residents as well as improved safety control, increased energy efficiency, accessibility to services, and overall satisfaction with a higher quality of life. The findings of this study are based on the review of papers selected from high-impact research journals, as well as an analysis of the most important industry tendencies and widely referenced literature on smart cities and resilient cities. As a result, this study examines the concepts of smart and resilient cities, as well as the relationship between smart city technologies, and resilient city indicators; the impact of technologies applicable in different smart city domains on city resilience is discussed. Finally, the conclusions on how proposed integration toward smart and resilient cities could be implemented for future cities' development are presented.

1. Introduction

More than half of the world's population lives in cities, and urbanization is increasing on all continents, with projections of more than 70% by 2050 [1]. Cities occupy only 3% of the area of the planet, but use 60% to 80% of their energy and emit 75% of their carbon emissions [2]. As a result of climate change, urbanization, dwindling oil resources, and natural hazards, cities must be better prepared for future shocks and strains and be able to withstand crises, the demand for sustainable cities is a consequence of global objectives [3] and recent epidemics [4]. Therefore, it is projected that the global market for smart city solutions and services will increase from $40.1 billion in 2017 to $97.9 billion in 2026, representing 12% of the Compound Annual Growth Rate [5]. Smart cities can help to address urbanization issues by stimulating change, innovation, and social elements. In addition, technologies such as information communication technology (ICT), Internet of Things (IoT), and artificial intelligence (AI) are widely used in cities to protect key facilities, increase the efficiency of the urban system, and manage disasters using smart urbanization techniques, such as continuous monitoring, data fusion, disaster warning,

decision making, and security planning [6]. Cities such as Mexico City, New York City, Rio de Janeiro, Tokyo, and other cities became 'megacities' with more than 10 million people in the 20th and 21st centuries, the relationship of the population with available resources, services, and infrastructure in these cities is leading to a demand for affordable housing, environmental management system, food supply, hospitals [7]. Cities are therefore going to find smart solutions to address these challenges and deliver a sustainable quality of life for citizens, improving mobility, safety, and a more connected environment.
The World Health Organization declared COVID-19, in December 2019, a new infectious respiratory disease, the most serious global health catastrophe since the Second World War. Due to rapid expansion around the world, the COVID-19 pandemic poses enormous health, economic, environmental, and social challenges to the entire human population [4]. The city must be able to absorb, adapt, and modify external challenges while maintaining public safety and the economy [8]. Therefore, smart city efforts have reduced the number of verified cases of COVID-19 by contributing to absorption by containing the risk of excessive transmission of the virus using smart solutions to tracking inflected cases by gathering spatial data from different sources: smartphones, transportation, bank cards, surveillance cameras, etc. Recognizing this, China and Singapore, for example, used smart solutions such as Closed-Circuit Television (CCTV), location systems, and cashless transactions implemented on biometric bracelets, smartphones, and smartwatches to monitor the exact location of influenced cases [9]. The Trace Together application in Singapore has been used to detect and store data of nearby infected cases, including the time of physical contact. The face detection system has helped China to trace and monitor people's movements effectively [10].
Financial and economic crises, population flows, environmental and climate phenomena, natural and anthropogenic disasters, social conflicts, and terrorism are just a few of the challenges cities face [11]. Therefore, resilience is generally understood as the ability and capacity of individuals, organizations, and structures to cope, adapt, and recover from shocks and stresses, in a way that reduces overall vulnerability to similar shocks and stresses in the long term [12]. At the city level, resilience is known as the capacity of cities to function and maintain continuity of services and functions throughout any shock or stress, while protecting and improving people's lives [13]. This article tends to explore the features that might integrate the smart city domains with the resilient city. Hence, the objectives of this review are as follows: (a) Investigate the importance of the smart city concept by noticeable developments in smart city research; (b) Analyze the importance of the resilient city in nowadays context; (c) Analyze the smart city capabilities to respond to the city resilience; (d) Conclude on how proposed integration towards smart and resilient cities could be implemented for future cities' development. The organization of the study is based as follows: Introduction; Methodology; Research results and discussions; Conclusions.

2. Methodology

The systematic review of the literature for this research was used [14] as a guide to identifying the related publications on smart cities and resilient cities to achieve the research objectives. The systematic literature review strategy was implemented in three main phases, as illustrated in Figure 1.
The goal of the literature review is to evaluate the current state of knowledge and the amount of research that has already been conducted. Firstly, the sound conceptual framework was chosen as the basis for the analysis of the research perspective of the concepts of the Smart City and the Resilient City, their developments, and measurement indicators. The following Research Questions (RQ) have been figured out based on the research objectives: RQ1: How do smart cities respond swiftly and effectively to global crises? RQ2: Is the smart city resilient? RQ3: What is the impact of smart city technologies on the resiliency of the city? RQ4: Could the smart city and resilient city concepts be integrated?
Secondly, a set of keyword phrases and Boolean connections were used to find the correct data. The following keywords have been identified to conduct the publication list: smart city, resilient city, smart city management, urban resilience, and sustainability.

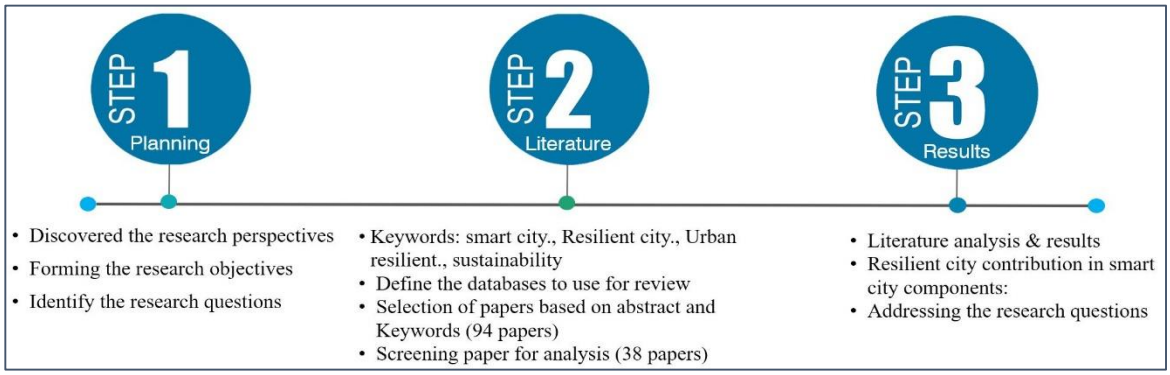

Figure 1. Methodology applied for systematic literature review.

The search was based on selected databases of high-impact research journals: ScienceDirect, Scopus, and IEEE which are widely utilized for literature search in several scientific domains setting eligibility and exclusion criteria. The selected papers reflect published literature between 2014 and 2022. Since most of the research on smart cities and their associated risks is published in these years, duplicated literature was removed before starting the literature analysis. Once relevant journals articles have been reviewed, scientific projects websites also have been screened. As a result, the search yielded 94 publications, including journals, books, conference papers, and policy documents. The filtering criteria were used to focus on various factors of the search strategy. This evaluation resulted in a final selection of 38 references that were used to address the defined research questions.

Finally, the deliverable results and the discussion seek to answer the research questions, the collected articles consider different aspects of smart city components, resilience city measurements, sustainability, and risk management. Different frameworks have been identified used for measuring the smart city[15] [16] [11] and resilient city[17] [18] [19, 20]. Therefore, the six dimensions for smart city assessment considered in this study are government, economy, mobility, environment, people, and living, in contrast, government, economy, environment, and society are considered for a resilient city domain.

The final section of this research provides a comprehensive overview of three ideas: smart cities, resilient cities, and the integration of the two concepts. as well as the conclusions and recommendations in this regard.

3. Research results and discussions

3.1 Smart City

The use of technology in a smart city improves the efficiency of the city's infrastructure, such as ICTs, which were used in their creation and construction to improve service performance, reduce resource consumption and costs, involve residents more actively and efficiently and improve their quality of life [2] as well as the environment [21].

The smart city concept began to gain traction in 2010, with increased academic research and policy discussions, particularly in the EU, where IoT concepts raise the importance and comfort of smart city living from various dimensions, thus creating a draw planning for tourists [22], this dimension is called the smart city components or domain. To assess these domains, Boyed Cohen [15] proposed in 2013 an indicator framework consisting of six fields used for a broad and deep evaluation of the attribute of smart cities named the ‘Smart city wheel’, which are smart Government, Economy, Environment, Mobility, People, and Living. Each field is divided into three subfields, including 62 indicators to assess more accurately the level of intelligence achieved by each city.

Today, the integration of IoT sensors, AI, and ICT with the smart city domain gives a new direction to the operation of city services, which respond automatically to the inputs they receive [21]. For example, researchers in Finland are working on a project called LuxTurrim5G in Espoo [23], by deploying a 5G network using street lighting poles. This project serves to provide a real-time digital picture for future investments based on the socioeconomic consequences of the city. These smart street lighting pole networks capture a large amount of data from integrated sensors. Outside of the campus, smart poles have also been placed. Nokia Data Marketplace, a local Blockchain-based data platform, receives and processes data from the poles. Using a shared data network and connection may significantly reduce the costs for mobile operators and digital service providers to build and operate their services.

A smart and sustainable city could be conceived as the fertile ground on which a resilient city bases its strategic vision. However, in moving from a digital city to a resilient city as shown in Figure 2, the scope and key elements of urban strategy continue to expand. The digital city aims to use ICT to digitalize society; the smart city aims to incorporate innovative technologies into urban processes, and the sustainable city aims to use technologies to reduce the impact on the environment of cities. Concerning the previous urban strategies, the resilient city merges all of these aspects, with a comprehensive vision that includes people, their well-being, and their participation in urban governance.

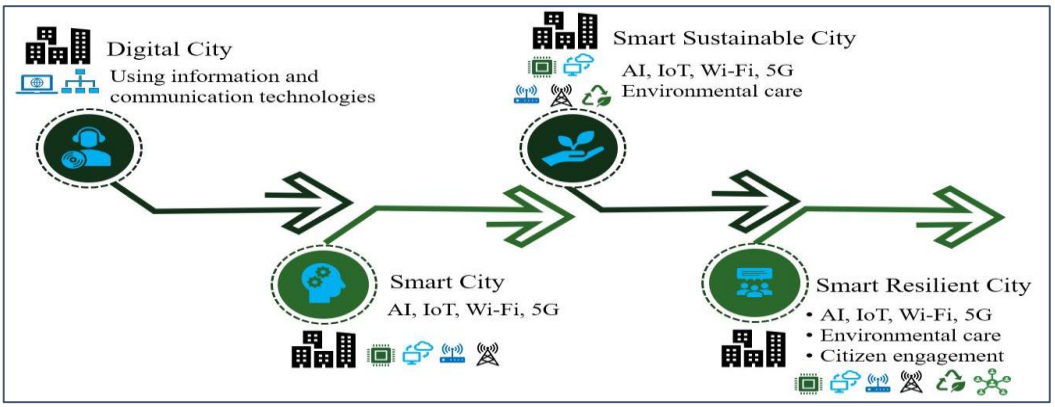

Figure 2. The smart city development.

3.2 Resilient City

Smart cities and urban resilience tend to be viewed as initiatives to improve urban performance and give methods and answers to urban challenges to improve human existence. Therefore, the smart city is supposed to take advantage of ICTs to engage people, improve municipal services, and strengthen the urban system, ultimately improving resilience and thus promoting urban sustainability. A smart city must always be resilient to unexpected events such as natural disasters. Therefore, various frameworks have been developed to assess the resilience of cities, such as the City Resilience Index (CRI) developed by ARUP company, which directly links and evaluates the development commitment and resilience properties [24]; the other frameworks focused on assessing resilience to natural disasters and environmental threats, such as the Climate Disaster Resilience Index (CDRI) developed by Joerin et al. [25] to reflect the ability of people and institutions to respond to potential climate-related disasters; the Urban Disaster Resilience Evaluation (UDRE) developed by Ya and Guofang in 2017 [26], PEOPLES developed by Cimellaro et al. to measure community resilience at different spatial and temporal scales [27]. Another framework was built to assess the smart city, which implies managing and identifying smart and resilient determinants while also delivering solutions to improve the city's infrastructure. Consequently, in 2021 Khatibi [20] developed the Baseline Resilience Indicators for Communities (BRIC) to study and rate the resilience of 187 smart cities [28].

Composite indicators or dimensions from several viewpoints provide the frameworks for discussing the city's resilience. For example, the BRIC framework proved that infrastructure and economic strength are determinant factors in overall resilience, among other indicators that are social, economic institutional, infrastructure, and community capital [28]. In the framework of CDRI [25], economic, institutional, natural, physical, and social components are included. Furthermore, [27] seven variables have been identified: population and demographics, environmental and ecosystem, organized government services, physical infrastructures, lifestyle and community competency, economic development, and social-cultural capital. Nel D and Nel V suggested a new way to integrate smart and resilient concepts, exploring the question of governance for a resilient smart city on a variety of scales to deal with climate change, environmental degradation, economic crises, and other issues [29].

As a result, smart cities must have robust plans to quickly restore their systems in the event of a disaster. A city's ability to adapt and recover from adversity is referred to as resilience. Therefore, cities,

particularly those in regions that are risk-averse, must increase their resilience capacity while implementing smart city principles. Post-disaster recovery and restoration is a unique opportunity for communities to address significant systemic issues to prevent future losses. Multiyear or short-term programs and task forces, aided by smart city technology on the horizon, can achieve urban resilience through many long-term or short-term activities [20].

3.3. Towards integration of smart and resilient city

This section seeks to address the research question of the smart city technologies adopted in various smart city domains help the city to increase its resilience. Most smart cities in the world have made efforts to improve their cities by creating a higher quality of life, enhanced governance against cyberattacks, giving rise to more business opportunities and investment, reduced traffic congestion, citizen awareness, and limited air pollution. Therefore, a resilient city role will mainly enhance the quality of life through public safety, adjustment to limited energy consumption, minimal environmental impact, and support for the social well-being of local citizens. Information Communication Technologies, Artificial intelligence, and IoT connections play a significant role in resilience by raising awareness, intelligence, and citizen participation [16].

Based on Zhu findings [30] there is enough space to enrich the view of a smart city by broadening the focus to a smart and resilient city by encompassing both human and ICT dimensions, which are considered irreplaceable pillars of future cities (Figure 3).

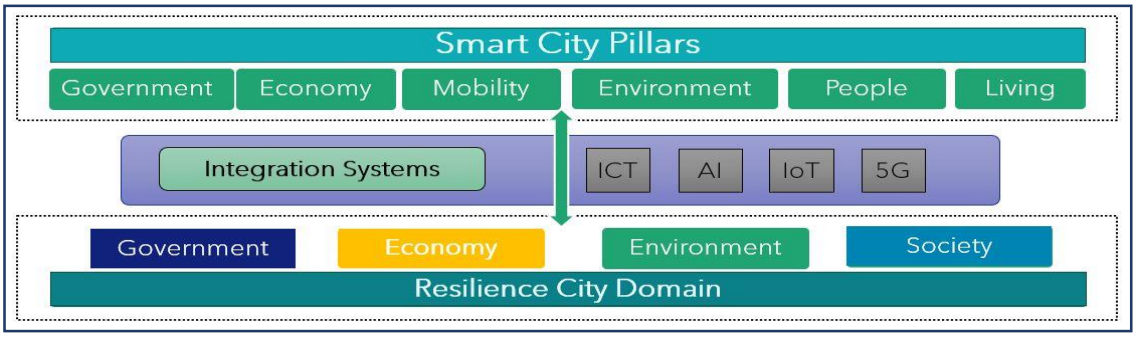

Figure 3. Towards Integration of Smart and Resilient City

3.3.1. Government. The awareness and preparedness of both public institutions and local communities, including citizens, to face current and future disasters are key success factors for renewed smart and resilient city governance, as already highlighted by the available literature. Big Data analytics, the Internet of Things (IoT), social media platforms, and other emerging and smart technologies are key to boosting resilience [31]. On the other side, cyberattacks are becoming more common in smart cities. For example, there have been widespread cyberattacks in the US cities of Atlanta, Baltimore, and the island of Sint Maarten in 2018 [32], affecting critical government services (police, evidence, and emergency services) and costing these communities millions of dollars. According to city officials in Atlanta, "decades' worth" of legal documents and "years" of police dashboard camera evidence were erased from their computers, with dire consequences for law enforcement. In Baltimore, emergency services estimated the cost of this attack at $2.2 million. In 17 hours that the computer-aided dispatch system was unavailable, responders were forced to make phone calls instead of using the system. Smart cities that rely on complex digital networks to manage thousands of city systems and services face the challenge that any device that relies on software to function is vulnerable to cyberattacks. The difficult part is translating smart governance principles into operational ‘smart and resilient urban governance’ and making them the substance of operations.

3.3.2 Economy. The smart city's economy takes numerous forms and applications, all based on cutting-edge research [11]. There are many examples of this, such as using internet services to share products and services such as transportation (vehicle or bicycle), accommodation, and fashion. Economic

sustainability can be improved by encouraging residents to maintain natural resources and supporting the city's resilience system by promoting positive social responsibility and accountability [33]. That is why urban resilience relies heavily on smart infrastructure and government administration in this aspect.

3.3.3 Mobility. Air, water, soil, and noise pollution is a major problem in the transportation mobility sector [34]. For the goal of decarbonizing transportation by 2050, the use of IoT sensors and self-driving vehicles is vital. For example, the Paris2Connect project in France aims to create a resilient strategy for the benefit of the community. The project shows how the collection of data from autonomous mobility services can be used for traffic management operations to reduce congestion and traffic time [23]. This solution reflects a positive effect on labour productivity by providing more alternatives for smart transport; also helps to integrate the most vulnerable citizens cycling, using bike parking facilities at the metro station into the labour market, increases road safety, and reduces the number of people injured in accidents [34]. TRES project [23] in the Belgian city of Leuven explores the transformation of digital light poles into intelligent urban infrastructure that allows city services to respond to situations more dynamically: measure air quality and limit energy consumption by only illuminating the area when people pass by. The other example of smart technology is how drones could be dispatched to assist firefighters and police officers. These devices would transmit aerial images of emergencies in real-time to those on the ground, allowing them to be better informed and respond more quickly.

3.3.4 Environment. Air quality control and monitoring, pollution reduction strategies, greenhouse gas emissions, water pollution index, number of people with respiratory diseases, noise pollution, etc. are just some of the environmental challenges that have presented themselves, as discussed by Sharifi [35]. The authors address whether sustainability assessment tools cover smart city indicators. Furthermore, ICTs can help speed up the transition to more sustainable and resilient cities by influencing the environment and the way people move. Hence IBM and Rio de Janeiro have teamed up to develop early warning systems for climate change-related emergencies, and this study illustrates how smart infrastructure solutions can help mitigate environmental emergencies [36].

3.3.5 People. Human capital has a high impact on the resilience of smart cities [18]. According to Kusumastuti et al. [37], the local government developed an internet website and mobile applications so that residents can obtain information about the city and share it on their social networks. The results showed that the residents' intentions to seek city information from the smart city digital platform are strongly influenced by social factors. According to the responses, respondents are most concerned about the platform's security/privacy/reputation and information quality. Analysis of the literature confirms the importance of not only ICT technologies but also the human dimension in the concept of the smart and resilient city, which includes participation, dialogue, and, above all, the collaboration between citizens, communities, and government, to conform [31, 37]. In this sense, a smart and resilient city is the co-designed and co-produced result of a participatory process of all stakeholders. Increased awareness, development, and education of citizens and communities are starting points.

3.3.6 Living. Smart buildings have the direct advantage of increasing the resilience of cities. Smart buildings are equipped with a variety of power generation capabilities (e. g., solar, batteries, generators) reducing dependence on external sources; digital and telecommunications infrastructure (such as cell networks, wi-fi, and IoT connectivity) may act as a microgrid leverage data; algorithms and its array of sensors inform, augment, and support human responses in critical situations (e.g., location of an incident, wayfinding, etc.). However, smart building systems provide the residents with local limited communications and operational functions in emergency and unplanned incidents [17, 38], thus the smart buildings have to be connected and integrated into the networks of the smart city from a resilient city point of view.

4. Conclusions

In conclusion, the results of the systematic literature review provided a lot of evidence that the smart city is capable of protecting its natural resources from excessive use and environmental degradation, ensuring social justice, and initiating urban economic development. It can be a prosperous, resilient, and sustainable city as it is digital and globally connected, characterized by smart governance, citizens, and adequate physical infrastructures and social services.

The resilience factor is an important element in smart city planning, thus highlighting the ability of the city to face disasters – to be prepared, to be able to absorb and recover - is essential in the context of nowadays. Local administrations and municipalities, as well as communities in large cities, especially in developing countries that are known to be vulnerable, are urged to follow the smart city paradigm to guarantee their resilience and sustainability.

The administrations of the cities have to consider investing in both ICT technologies of city infrastructure to ensure up-to-date functionalities and information flow and in addition to citizens and communities through educational services to foster the development of a smart and resilient city.

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