Chapter 5
Resilient-Smart Cities: Theoretical Insights

Ke Xiong, Ayyoob Sharifi, and Bao-Jie He

Abstract Cities, the main settlements of human beings, are facing mega challenges of climate change, urbanization, population increase, economic growth, and environmental deterioration. To address such challenges, the goal of sustainable cities and communities has been advocated by the United Nations. In particular, smart city has been applied to integrate digital technologies and sensors to improve the efficiency of assets, resources, and services in urban operations. In comparison, the resilient city is expected to improve urban resilience (e.g., prevention, impact reduction, recovery, adaptation) to disasters and emergencies. However, limited studies have analyzed how to ensure a normal condition for smart city under extreme conditions and how to ensure a resilient city can efficiently respond to disasters and extreme events. Therefore, this chapter aims to address such research gaps for the integration of smart city and resilient city, namely resilient-smart city, in order to better ensure sustainable urban development under various mega challenges. This chapter discusses how six components of smart city (i.e., governance, people, life, mobility, economy, and environment) contribute the resilient city in four aspects of health and well-being, economy and society, urban systems and services, and leadership and strategy to indicate the possibilities of the integration of smart city and resilient city. Moreover, this chapter points out challenges hindering resilient-smart city development and provides corresponding suggestions to overcome such challenges. Overall,

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this chapter is expected to open a vision for further development of resilient-smart cities that can contribute to the achievement of sustainable urban development goals.

Keywords Smart city · Resilient city · Information and communications technologies · Internet of things · Assessment indicator system

5.1 Introduction

The Earth and human beings have been facing several mega challenges such as climate change, environmental deterioration, rapid urbanization, and unbalanced and unbridled economic development in recent years. In particular, following global urbanization, one of the most transformative trends (Korhonen and Snakin 2015), such challenges in cities are more prominent. For instance, while cities are the home to only 55% of the world population, they consume about 67% of global primary energy and emit more than 70% of the greenhouse gases (IPCC 2014). By 2030 when the urbanization rate reaches 60%, nearly 75% of carbon emissions and energy consumption will be concentrated in cities (Kennedy et al. 2014). Moreover, while cities only account for 4% of the land on the Earth (Pouffary and Rogers 2014), they will accommodate nearly five billion people by 2030. Accordingly, various problems, such as traffic congestion, environmental pollution, urban climate change, suitable housing, and safety are also critical (Gasco-Hernandez 2018).

There is an urgent need to control, alleviate, and address such challenges to provide citizens with basic needs of urban infrastructure and ensure the sustainability of society, economy, and environment (Eremia et al. 2017; Macke et al. 2018). In the last decade, development of smart cities has been widely recognized as an important approach for enhancing urban management capacity to deal with such challenges (Albino et al. 2015; Bansal et al. 2015), and many cities have practically implemented smart city projects. For instance, the city of Dubuque, Iowa, United States, digitized and connected all resources of the city, including water, electricity, oil, and natural gas, for intelligently reducing urban energy consumption and costs, while meeting citizens' needs through monitoring, analysis, and integration of various data (use 2009). The 'Your accessible transport network' plan, by Transport for London, is a project for the improvement of transport capacity and services across London, England, through the collection of real-time information from subway cards, mobile phones, and social networks and prompt and effective responses (TfL 2012). Partly due to the effective operation of this system, during the 2012 Olympic Games when users increased by 25%, the transport system in London still worked well (TfL 2013).

Cities, the main human settlements, are becoming increasingly important to secure citizens with sound and holistic functions. Under many extreme conditions (e.g., extreme weather, natural disasters, pandemic, and other emergencies), cities are required to be resilient to reduce associated losses and recover from potential impacts. To achieve so, it is necessary to adopt measures to improve a city's capability and capacity in dealing with disasters while ensuring that there are sufficient resources to reduce or avoid the harm caused by sudden disasters to cities and their inhabitants (Sharifi and Khavarian-Garmsir 2020). Developing resilient cities has been suggested as one of the solutions to such extreme conditions. Resilient city initiatives aim to strengthen the planning, coping, recovery, and adaptability of cities to a wide gamut of adverse events, including climate-induced disasters and natural disasters. For instance, after the Sandy storm, the United States developed disaster management and response systems under long-term climate change risks, in order to quickly recover facilities and services in cities. Gorakhpur, India, a city under the severe influence of urban flooding and the associated impacts of dengue fever, malaria, and Japanese encephalitis, mainstreamed resilient solid waste management systems and upgraded the drainage and sewerage system to improve urban resilience to urban flooding (Du 2019). Overall, to overcome urban challenges and secure safe, comfortable, and livable urban environments, both smart city and resilient city have attracted extensive attention of scholars and decision-makers in recent years (Sharifi et al. 2021; Zhu et al. 2019).

5.1.1 Concept and Development of Smart City

The smart city paradigm was first proposed at an international conference in San Francisco, California, in 1990, with the theme of 'smart cities, fast systems, and global networks', shedding a light on how technologies can reshape cities (Gibson et al. 1992). In the following years, its connotation gradually expanded (Fig. 5.1). Until 2008, the 'Smart Earth' proposed by IBM (full name: International Business Machines Corporation) was aimed at applying smart technologies to all aspects of life (e.g., medical care, transportation, currency, and infrastructure) and thereby making the planet increasingly intelligent. Afterward, there has been a clear vision of smart city among the public (Paroutis et al. 2014). In particular, a smart city covers a relatively broad range of views (Dong et al. 2020), while the conceptual understanding of smart cities is mostly relevant to technology, economy, management, etc., judging

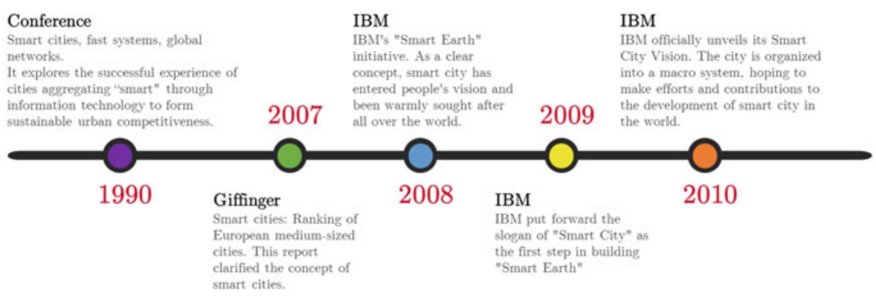

Fig. 5.1 Development of the smart city concept. 1990s (Gibson et al. 1992); 2007 (Giffinger et al. 2007); 2008–2010 (Paroutis et al. 2014)

from existing studies and findings (Zhang 2019). In addition, more recently, there has been an increasing recognition of non-technological and soft dimensions of smart city. For instance, the role of people as the end users of smart cities is increasingly emphasized (Sharifi 2019, 2020b).

At the technical level, a smart city captures the information of an entire city and conducts data analysis to achieve real-time monitoring of urban resources. Accordingly, a smart city is defined as an urban area that integrates information and communication technologies with traditional infrastructure and employs new digital technologies for coordination and integration of urban functions and operations. A smart city, therefore, is a tool or platform, capable of increasing competitiveness and thereby improving communities and quality of life (Batty et al. 2012). For example, using video surveillance and big data analytics can contribute to ensuring urban safety supervision and early warning more quickly and intelligently.

At the economic level, smart city approach can contribute to creating urban areas where the economy has achieved smart growth, and smart industry accounts for a large proportion of urban industry with a high growth rate (Davis and Weinstein 2003). For instance, emerging industries of smart motor systems, smart logistics, smart buildings, and smart grids have been the economic engine of many cities. Because of the significant reduction of carbon emissions, more importantly, such industries are important drivers to low-carbon economy (The Climate Group and Global eSustainability Initiative 2008). Smart economy also entails further promotion of start-ups and better training of people to enable them to be active contributors to the digitalized economic system (Sharifi 2019).

At the management level: A smart city refers to the utilization of modern technologies such as Internet of Things (IoT) that are being explored and tested, big data, and cloud computing, to enable urban infrastructure and services (e.g., urban management, education, health, public safety, transportation, power grid, and water resources) to be intelligent, interconnected, and efficient. Such an approach makes cities manageable, practically promoting sustainable urban development and improving people's quality of life (Han and Hawken 2018; Lytras and Visvizi 2018; Maye et al. 2016).

5.1.2 *Concept and Development of Resilient City*

The resilient city generally indicates a city should be able to face either internal or external shocks and still maintain its main functions during disasters or crisis events (Sharifi 2016; Sharifi and Yamagata 2018). Such an expectation enables resilient city to receive wide attention and efforts across various disciplines, such as ecology, urban planning, economics, and sociology. Resilience idea was originated in disciplines such as physics and psychology and then applied to other fields such as ecology. In ecology, it aims to uncover the fluctuations and interactions between two competitor communities in the biosphere. Its scope gradually expanded from natural ecology (i.e., the relationship between stability and diversity in the ecosystem) to human ecology (i.e., the ability of cities to respond to climate change by changing the political structure) (Bahadur and Tanner 2014).

In summary, research efforts on resilience have gone through three stages (Fig. 5.2), including engineering resilience (Alexander 2013), ecological resilience (Holling 1973), and social-ecological resilience (Berkes and Folke 1998). Engineering resilience is to describe the capability of a single and static system in restoring the original balance and maintaining system stability after being subjected to external shocks, showing an orderly and linear characteristic. Ecological resilience emphasizes the ability to adapt to external shocks and to characterize the robustness of a complex system with complex and nonlinear changes (multi-equilibria system). Social-ecological resilience emphasizes that humans and nature are regarded as a whole, and different levels of systems interact with each other to form a dynamic equilibrium process. Social-ecological resilience has a strong ability of learning and adapting with a certain degree of variability and innovation (Holling 2001).

While there have been several decades since the resilience was proposed, the definition of resilience is still not universal given its broad application in many disciplines (Sharifi 2020c). Among various definitions, Holling first put forward the theory of 'hierarchical structure, chaos, adaptive cycle' (Holling 1973), which explored the connotation of sustainable development and laid the ideological foundation for the formation of urban resilience theory (Zhao et al. 2020). Professor Mileti at the University of Colorado in the United States who introduced the resilience concept into urban planning pointed out that *a resilient city mainly responds to climate change and resists disasters through the construction and improvement of urban physical environment and infrastructure* (Mileti 1999). UN-Habitat pointed out that *a resilient city assesses, plans and acts to prepare for and respond to all hazards – sudden and slow-onset, expected and unexpected* (UN-Habitat).

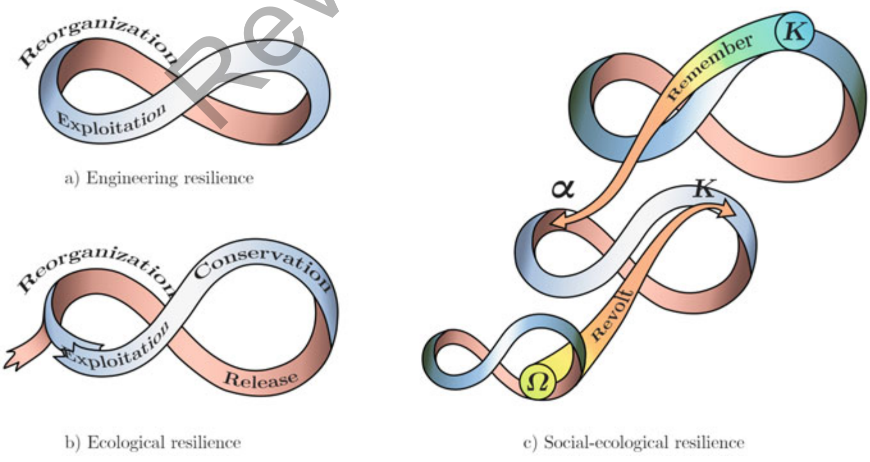

Fig. 5.2 Characteristics of resilience concept in different stages (*Source* Gunderson and Holling 2002)

Meerow and others provide a more systematic and comprehensive interpretation of resilient cities (Yan and Tang 2020), by defining a resilient city as '*the urban system and its social-ecological-technical networks at all time and space scales maintain/recover in time to the required functions when disturbed and adapt to changes and rapidly transform systems that limit current or future adaptive capacity*' (Meerow et al. 2016). Furthermore, the International Council for Regional Sustainable Development (ICLEI) mainstreamed the topic of 'Resilient City' and introduced it into studies on cities and disaster prevention. Since then, urban resilience has received extensive attention and (Motesharrei et al. 2016) and is now a critical and hot topic in urban planning and urban geography. Moreover, many countries and organizations including the United States, Britain, Australia, Japan, etc., have formulated development strategies, policies, and projects based on the 'resilience' theory (Table 5.1).

Table 5.1 Strategies, policies, and projects for the development of global representative resilient cities

Country/organization	Strategy/policy/project	Source	Time
Hyogo Prefecture, Japan	Hyogo Declaration	https://undocs.org/en/A/CONF.206/6	2005
London, England	Managing Risks and Increasing Resilience	https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/managing-risks-and-increasing-resilience-our	2011
UNDRR	Making Cities Resilient	https://www.undrr.org/publication/making-cities-resilient-report-2012	2012
New York, USA	A Stronger, More Resilient New York	https://www1.nyc.gov/site/sirr/report/report.page	2013
Toronto, Canada	Resilient City—Preparing for a Changing Climate	https://www.toronto.ca/legdocs/mmis/2016/pe/bgrd/backgroundfile-98049.pdf	2013
Rockefeller Foundation	100 Resilient Cities	https://resilient-cities.sphaera.world	2013
USAID	The Building Community Resilience in Timor-Leste	https://www.usaid.gov/timor-leste/project-descriptions/building-community-resilience-timor-leste	2014
Earthquake Emergency Initiative	Urban Resilience Master Planning	https://emi-megacities.org/urban-resilience-master-planning/	2015
The Commonwealth of Australia	Building a more secure and resilient Australia	https://budget.gov.au/2021-22/content/download/glossy_resilient.pdf	2021

In summary, existing understandings indicate that smart city and resilient city concepts present their consistent expectations in *making cities and human settlements inclusive, safe, resilient and sustainable* (Goal11, UN SDGs). A smart city concentrates on improving efficiency, capacity and performance of assets, resources, and services (e.g., transportation, utilities, and many public spaces such as libraries, hospitals, museums, and exhibition halls), along with the growth in societal needs and increasing urbanization. A resilient city is expected to improve urban safety and resilience during urban crises and extreme conditions, protecting people from direct economic losses and deaths, and quickly recovering urban systems to normal.

Both smart city and resilient city could generate complementary benefits in improving urban sustainability. On the one hand, a smart city technically integrates intelligent methods and sensors for real-time monitoring urban situations and generating immediate and prompt responses. This is vital for the development of resilient city to obtain useful and critical information that is unavailable with only physical approaches under crises and extreme events, to support effective decisions and strategies for overcoming extreme events. On the other hand, a resilient city aims to secure human beings, ecosystem, assets, resources, and services, which is a critical premise of a smart city for higher efficiency, larger capacity, and better performance. In addition, the operation of digital methods and sensors in providing real-time urban services requires a safe and resilient environment, particularly under crises and extreme events. Integrating resilient city and smart city by developing resilient city smartly and enhancing smart city resilience should be an important issue for the achievement of *Sustainable Cities and Communities* (Goal11, UN SDGs) under mega challenges of climate change, environmental deterioration, urbanization, and economic development. However, existing studies have considered smart city and resilient city separately and only a few studies have explored the integration of smart city and resilient city (Hassankhani et al. 2021; Sharifi et al. 2021). To fill the gap, this chapter aims to explore the potential of integrating smart city and resilient city concepts for the development of resilient-smart cities, particularly to enhance the robustness and quality of both resilient city and smart city with the inclusion of information technologies and smart solutions such as big data and Internet of Things.

The remainder of this chapter is structured as follows. Section 5.2 describes why the integration of smart city and resilient city is needed. Section 5.3 presents the contribution of smart city integration for urban resilience. Section 5.4 discusses the challenges and opportunities for integrating smart city and resilient city, and proposes relevant suggestions. Finally, Sect. 5.5 summarizes and concludes this paper.

5.2 The Need for Resilient-Smart Cities

Both smart city and resilient city provide a path for city optimization and upgrading under various challenges. As shown in Fig. 5.3, smart city is capable of addressing a broad range of urban problems, like resource shortages, traffic congestion, environmental pollution, etc. In comparison, resilient city is expected to address severe

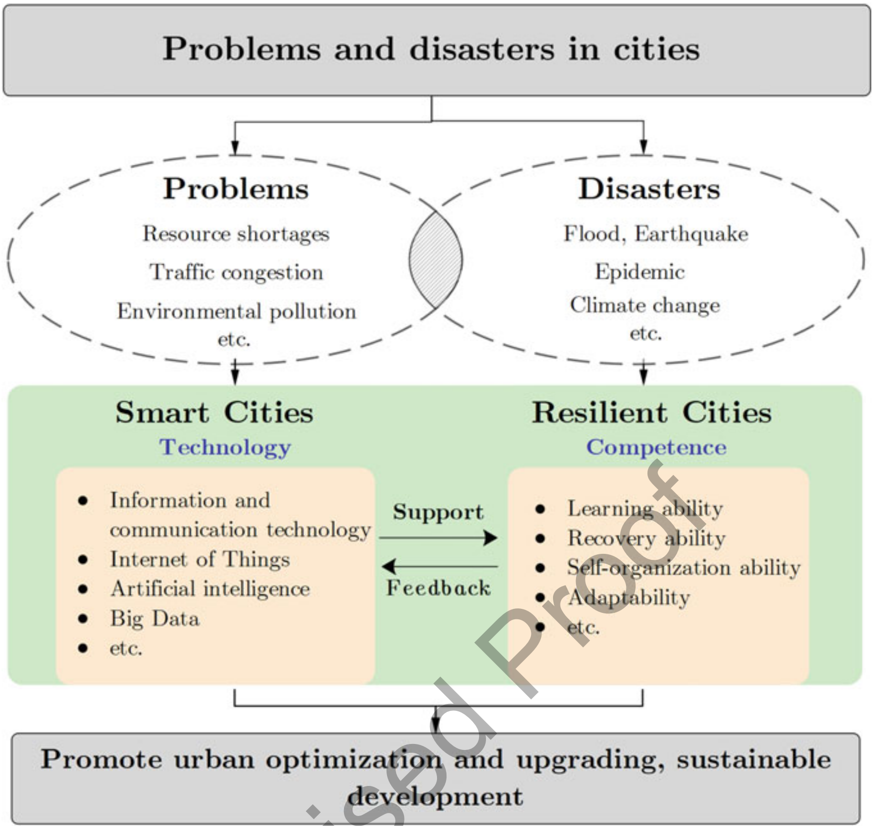

Fig. 5.3 Ways to promote urban development of SC and RC

problems caused by major disasters with strong consequences on environments, lives, economy, etc. While smart city presents a technical means of urban development by integrating information and communication technologies for real-time sensing, analysis, and integration of various key information of the core system for urban operation, smart city is compromised to quickly cope with disasters and reduce associated impacts. Therefore, there is a need to improve the capability of smart city in dealing with urban disasters rather than only day-to-day problems.

Resilient city can respond to and resist adverse situations of urban flooding, extreme heat, emergencies, pandemics, etc., but it is difficult to quickly identify disasters, promptly predict risks, and effectively generate decisions to resist and respond to disasters using traditional methods. Accordingly, it becomes important to improve the efficiency of addressing disasters by shortening response time and avoiding problems evolving into disasters. Such a consideration is consistent with the current trend of resilient city studies, where the main themes have been shifting to prevention before light disasters from overemphasizing recovery after severe disasters (Meerow et al. 2016). This should be supported by the inclusion of new measures and technologies and explore novel paths and models.

To enhance capacity and performance of smart city and resilient city, accordingly, this section suggests the integration of resilient city and smart city, namely resilient-smart city, for an innovative model of urban development and support for a city to conduct sustainable construction in an all-round way, thereby approaching the goals of inclusive, safe, resilient, and sustainable cities and communities. As shown in Fig. 5.3, smart city and resilient city complement each other for achieving sustainable urban development. On the one hand, the resilient city cannot be separated from the management technology of smart city, where smart city provides technical support. On the other hand, resilience provides positive feedback by enhancing urban resilience to ensure the healthy development of smart city. The needs for resilient-smart city are fourfold as follows.

First, the smart city provides a technical support for the development of resilient city in terms of information and communications technology. Moreover, the technology-based response features of smart city can be a management plug-in module for resilient city, making up for shortcomings (e.g., unavailability of real-time information and data, lack of evidence-based and effective decisions) of resilient city. Modern information and communications technologies such as the Internet of Things and big data analysis technologies provide open opportunities for the development of resilient city (Shah et al. 2019). The integration of smart city solutions in resilient city initiatives covers a wide scope of practices, such as real-time crime monitoring maps, predictive policing and security staff, natural disaster (climate risk) monitoring and assessment, urban information management, and urban disaster relief and disaster prevention and mitigation systems (Desouza and Flanery 2013; Kontokosta and Malik 2018; Takewaki et al. 2011; Zhang et al. 2019). During the COVID-19 pandemic, for instance, information and communications technology and big data combined relevant data with geospatial and temporal information to track data and build a complete information monitoring and dissemination platform. It allowed people to grasp essential data timely, thereby hindering the spread of the pandemic and minimizing adverse impacts (Sharifi and Khavarian-Garmsir 2020).

Second, smart city supports disaster prevention in the development of resilient city given its capability of monitoring and managing infrastructures such as transportation, buildings, electricity, and water in achieving energy and resource efficiency. For instance, the regular detection of conditions of underground water pipelines, tracking and investigation of the cleanliness of pipelines in a real-time manner by the municipal government of Paris, France, using geographic information systems, provides a database to implement intelligent management of underground drainage system and improves water efficiency on the one hand. On the other hand, it offers urban hydrological systems and stormwater infrastructure management required to improve resilience to flooding (esri 2019; WRT 2010).

Third, sound development of smart city requires positive feedback from resilient city, because smart city, an important factor for achieving urban sustainable development, has an endogenous relationship with the improvement of urban resilience

(Song 2020). However, the pure embedding of information and communications technologies into urban infrastructure and operation management systems does not necessarily promote the healthy and safe development of cities (Boulos et al. 2015). Resilient city acts as a foundation for smart city planning (Moraci et al. 2018). For instance, the increasing high temperature in cities is a challenge to the normal operation of sensors and transmission systems, where development of heat-resilient cities for cooling cities and communities is an important prerequisite.

Fourth, the information security is also an important issue in building resilient cities to determine the performance and outcomes of smart city. Therefore, resilient city, a positive feedback to emergencies, should quickly adapt to current or future systems and overcome the negative impact of smart city on social development (Hiller and Blanke 2017). For example, the SusCity project in Lisbon, Portugal, adopts a new architecture of the Internet of Things, using protection and recovery modules to analyze faults, take measures to solve them, and provide positive feedback on the Internet of Things infrastructure in the smart city environment to reduce the adverse effects of technology (Abreu et al. 2017).

5.3 Smart Cities for Urban Resilience

Conceptually, the application of smart city technologies helps improve urban resilience and the improvement of urban resilience generates positive feedback to the quality and performance of smart city. Nevertheless, it is worth discussing how smart city technologies can contribute to urban resilience, in order to identify possibilities of resilient-smart city development, given the fact that application of smart city technologies can potentially impede urban resilience. A typical case is that smart city is vulnerable to cybersecurity attacks that may detract from urban resilience (Beck 2017). This section starts with the analysis of the assessment indicator systems of smart city and resilient city, following which the possible contributions of smart city to urban resilience are analyzed in four aspects including health and well-being, economy and society, infrastructure and ecosystems, and leadership and strategy.

5.3.1 Assessment Indicator System for Smart City and Resilient City

As aforementioned, scholars have made various attempts to define the smart city concept in different disciplines such as technology, economy, and management. The frameworks which they have presented to assess city smartness in these different disciplines also vary (Sharifi 2020a). The most typical frameworks include the smart city model for European cities developed by Giffinger and Gudrun (2010), the basic component of smart city model by Nam and Pardo (2011), the smart city initiatives framework by Chourabi et al. (2012), and the Smart City Wheel (SCW) by Cohen (2013). Among these frameworks, the Smart City Wheel (Fig. 5.4) represents one of the most prominent concepts and characterizations of smart city. It is constructed based on six critical dimensions, including governance, people, life, mobility, economy, and environment proposed by (Giffinger et al. 2007). These dimensions are also widely accepted and used by other scholars, enterprises, and governments for smart city research, assessment, and building (Dong et al. 2020).

The framework of the City Resilience Index (CRI) (Fig. 5.5), proposed by the Rockefeller Foundation, is one of the most holistic ones for resilient city assessment (Wei et al. 2017). This framework presents a comprehensive set of indicators, variables, and metrics that are related to urban resilience (ARUP 2014), in four dimensions including health and well-being, economy and society, infrastructure and ecosystems, and leadership and strategy. Each of these dimensions consists of three

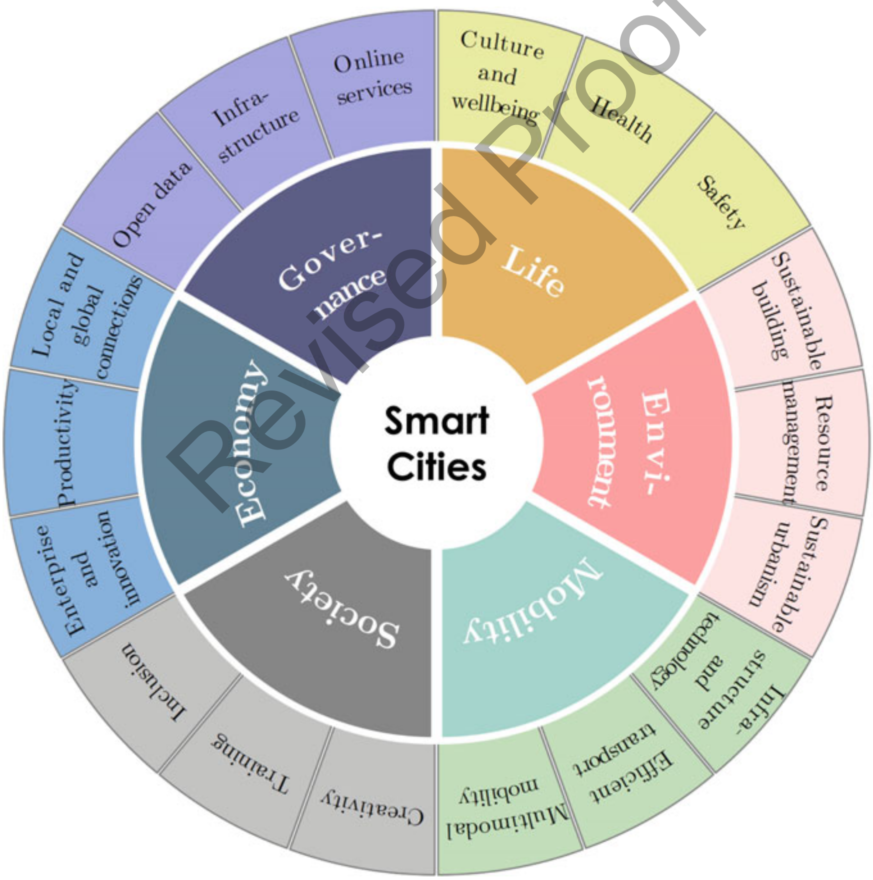

Fig. 5.4 Assessment indicator system of smart cities (*Source* TUWIEN 2015)

Fig. 5.5 Assessment indicator system of resilient cities (*Source* ARUP 2014)

indicators following the principles of feedback, robustness, redundancy, richness, and tolerance (ARUP 2014).

Both SCW framework and CRI framework comprehensively cover several urban components. Such components could overlap and supplement to a certain content, offering the opportunities to identify connections between smart city and resilient city. For instance, resilient city is expected to provide adequate safeguards to human life and health in the CRI framework, and smart city should ensure people's health and safety in the SCW framework. The urban systems and services defined in the CRI framework are enabled by diverse and affordable multi-modal transport systems and information and communications technology networks, and contingency planning. Such a vision indicates that the integration of smart city technology into the construction of resilient city has initially been considered in resilient city framework. In the following parts, the connections between smart city and resilient city, namely the contribution of smart city to urban resilience, will be detailed. In particular, six

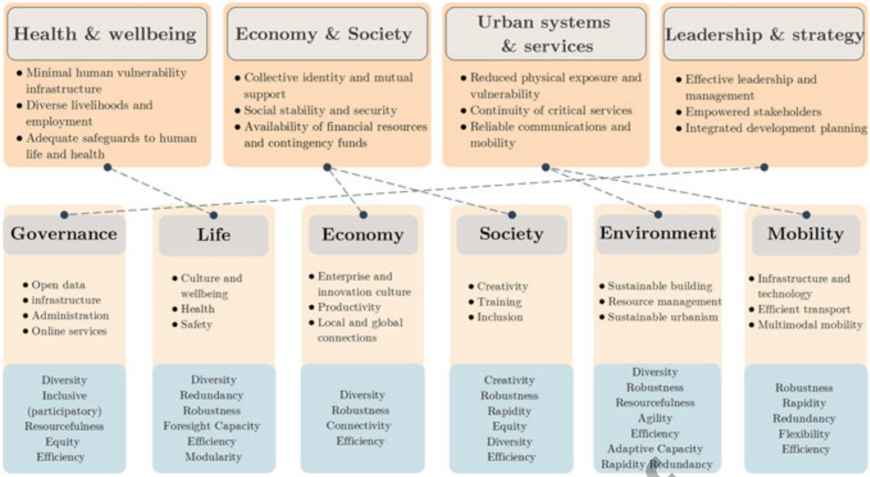

Fig. 5.6 Connections between smart city and resilient city

scopes of indicators in the smart city assessment indicator system are linked with the four scopes in the resilient city assessment framework (Fig. 5.6).

5.3.2 Health and Well-Being

The category of health and well-being indicates to what extent a city meets the basic needs of citizens. It is characterized by three indicators including minimal human vulnerability, diverse livelihoods and employment, and adequate safeguards to human life and health. Using information and communications technology or other modern technologies, smart life contributes to these three indicators, reflecting the characteristics of urban resilience such as integration, systems-based operation, anti-disturbance, redundancy, robustness, and rapidity.

First, smart life ensures the basic needs such as water sanitation, energy, and food. In terms of water, for instance, smart life is engaged to assess and manage water resources through monitoring and dispatching systems, recycling and reuse systems, and ensuring water quality and safety so as to efficiently and reasonably meet the needs of stakeholders and realize the smart governance of urban domestic sewage. A case of New York, United States, is that smart city technology was applied in the planning process by deploying sensors in the urban underground pipe network for monitoring the operation of water resources. Another case is the installation of 24 weather monitoring stations of Vienna Pipe Network Company, through the close cooperation with the National Meteorological Administration, for timely forecasting of the rainstorm direction and precipitation and sending feedback to the control center, to follow up the intelligent management and control of the drainage network (Marks 2014).

Second, new technology applications (new media, communication equipment, semiconductors, wired and wireless services, and other diversified companies) for smart life can support economic development, thereby providing more opportunities of access to finance, skills training, and business support. For example, Toronto, a city with a high concentration of information service enterprises, has approximately 148,000 employees in the information service industry in the metropolitan area. The information service industry contributes an annual sale of more than $32.5 billion and its annual export value exceeds $6.2 billion (TOP 2018).

Finally, smart life enables cities to collect relevant information through early detection and rapid response to crises or emergencies (Yao and Wang 2020), to coordinate disaster relief work, assess the degree of damage to urban system, and further strengthen the resilience of urban system. It is an approach to improve urban resilience to disasters (Fujinawa et al. 2015) and ensure urban dwellers' health and safety. There have been many practical cases of crises detection and response in smart life. The integrated sensors in Buffalo Bay Park in Houston, United States, provide disaster prevention information by detecting behaviors and degree of hurricane and flood danger for reducing associated losses to a certain extent (Jason Iken and Brown 2009). During the COVID-19 pandemic, information and communication technologies and big data analytics were utilized to combine relevant data with geospatial and temporal information to enable people to grasp relevant data as promptly as possible, thereby controlling the spread of the epidemic, minimizing its impact, and enhancing the resilience to the pandemic (Sharifi and Khavarian-Garmsir 2020). Singapore's urban public safety supervision system plan facilitates rapid detection, real-time response, and coordination of events that affect urban public safety. This is achieved through unified supervision, information integration, efficient coordination, network integration, information interaction, and data sharing between different urban public safety services and monitoring systems.

Smart life can also adopt information and communications technology that integrates health facilities and services, and responsive emergency services, providing faster and more convenient services. For example, many megacities such as Tokyo and New York adopt electronic medical record systems to integrate various clinical information systems and knowledge bases, set up sensors and wireless networks, and adopt a series of technical measures such as cloud computing. These technologies greatly enhance diagnosis and treatment activities of the medical staff and improve the accuracy of medical procedures. In addition, online medical information exchange system and mobile medical applications have been developed to provide residents with medical and health services anytime and anywhere, realizing the dynamic transmission of the physiological conditions of family patients and ensuring resident's health and safety. Such services are also expected to provide other resilience co-benefits. For instance, telemedicine minimizes the need to visit hospitals and medical centers, thereby allowing remote access in case of disruptions in the transportation network or when social distancing is needed as was the case during the COVID-19 pandemic (Sharifi et al. 2021). Additionally, through reducing travel demand, telework can contribute to climate change mitigation efforts as transportation sector is one of the major contributors to greenhouse gas emissions (GHGs).

5.3.3 Economy and Society

Economy and society need a collective identity and mutual support, social stability and security, and availability of financial resources and contingency funds. A smart economy is characterized by an innovative spirit, flexibility of labor market, international embeddedness, ability to transform, and so on (TUWIEN 2015). It can be diverse, robust, connected and efficient. Among other things, the characteristics of smart society include affinity to lifelong learning, flexibility, creativity, and people's participation in public life (azbil 2019). Smart society is capable of promoting the flexibility, creativity, robustness, rapidity, equity, diversity, and efficiency in cities.

Smart economy provides sound management of city finances and diverse revenue streams. In particular, a wide application of information and communication technologies (i.e., electronic medical treatment, electronic technology products, etc.) provides advantages to attract enterprises' investment and talents. Data mining and visualization of smart economic decision-making and operations, such as the sharing economy, improve economic diversification and capital flow allocation efficiency and make urban economy management more comprehensive. In addition, the economic dimensions of a smart city can provide strong support for disaster prediction and preparation, disaster reduction, and recovery. It is also the basis for the development of smart infrastructure and government management (Oliva and Lazzeretti 2018). Toronto has attracted many world-leading high-tech companies by its advanced information and communication services. Built upon the information service industry and cluster development strategy, Toronto has become one of the most innovative research and investment hubs around the globe. Through attracting private sector developers to provide start-up capital, Toronto's Lakeside Community has built a new cutting-edge network facility, which in turn, creates new opportunities for the community to attract more digital media and other innovative companies (TOP 2018).

In addition, the application of blockchain improves the reliability and transparency of transactions to ensure the security of financial and other transactions (Desroches and Taylor 2018) and provide support for sound management of city finances, which is of significance for a well-functioning city. As a supplement to the traditional economy, 'sharing economy' guarantees the normal establishment of a part of the supply–demand relationship. While striving to maintain normal operations, different social forces share the risks associated with shared resources, shared services, and shared technologies (Long 2020), greatly improving the allocation and utilization efficiency of various resources in a city.

Smart society development not only guarantees a safe and stable operation of medical care, office, teaching, etc., but also promotes social relationships and networks, integrated communities. First, it provides a cross-domain linkage for disease prevention and control (e.g., 'Healthcare' in Hong Kong), which improves the accessibility of medical information. Second, with the employment of information and communication technology, smart society promotes closer and more effective connections within and between enterprises or schools, improves the fairness of educational resources, and enhances the effectiveness of social management. Given the needs of COVID-19 prevention and control, applications of remote collaborative office and distance education are also emerging rapidly (Wen 2020). In particular, the remote collaboration and cloud office systems have been developed and optimized to provide technical support for employees to work at home during such special periods. The adoption of DingTalk and other network platforms has been prevalent for large-scale online teaching to minimize the impact of the epidemic on normal teaching. Overall, these applications are typical cases that greatly improve the efficiency of remote information collection and communication and facilitate better work-life balance (Li and Long 2020). Such approach to smart society development provides support for the speed, fairness, and diversity of resilient cities. Third, the use of technology and new media in smart society improves public awareness of environmental protection and disaster self-rescue, thereby enhancing risk reduction, recovery, and learning and innovation capacities. Hangzhou city in China, for instance, has developed a comprehensive security experience hall through video surveillance, simulation operations, game interaction, and Virtual Reality (VR) virtual experience. This allows residents to learn various hazard safety measures and prevention skills that are closely related to life and strengthen residents' awareness of safety precautions.

5.3.4 Urban Systems and Services

Resilient urban systems and services could be assessed by three indicators of reduced physical exposure and vulnerability, continuity of critical services, and reliable communications and mobility, which have a close connection with the smart environment and smart mobility. For the smart environment, one of the assessment indicators is sustainable resource management, in order to make environment management sounder and critical infrastructure safer. This, at the same time, indicates smart environment embodies the diversity, robustness, resourcefulness, agility, efficiency, adaptive capacity, rapidity, and redundancy of a resilient city. Smart mobility is consistent with the goal of reliable communications and mobility in resilient cities, in terms of integrated transport networks, information and communications technology, and emergency communication services. This makes it related to resilient city principles of robustness, rapidity, redundancy, flexibility, and efficiency.

Sustainable management of smart environment facilitates sustainable building and resource management and contributes to meeting demands of critical infrastructure, optimizing resource allocation in energy supply, and strengthening urban monitoring systems to alleviate deterioration and improve restoration of ecological systems. Many countries and regions have implemented smart environment measures to address a variety of problems emerged in urban development (e.g., increased demand on critical infrastructure, ecosystem degradation, etc.). A case of the critical infrastructure is the Huoshenshan and Leishenshan Hospitals in Wuhan China that were built with high quality standards in a short timeframe in the early stage of the COVID-19 outbreak, using prefabricated rapid construction and Building Information Modelling technologies. This provides efficient and accurate support for building and infrastructure construction in response to emergencies (Li and Long 2020). With the extensive use of renewable solar energy resources, Barcelona has developed a smart energy management (e.g., energy-saving management mode) system for buildings, water supply systems, information billboards, charging infrastructure, etc., and the city is among those with the highest density of solar panels in Europe (ZIGURAT 2019). Different types of electronic trash bins, where trash cans are connected to underground pipelines through their respective valves, have been built in Stockholm to classify and sort trash (Fourneris 2020). Moreover, waste treatment efficiency has been also improved by automatic control system, high-speed transportation system, and automatic separation and transportation systems.

Smart environment systems can automatically collect and monitor various resources related to the human living environment such as water, electricity, and atmosphere in real time. The systems detect and deal with various adverse events in time and continuously carry out plans to establish more comprehensive ecosystem management and flood risk management systems to ensure cities operate resiliently. For example, cities can build smart grids to promote on-demand mutual conversion and distribution of energy on a unified platform and encourage innovative methods for increased uptake of clean and renewable energy sources and technologies (Gargiulo and Zucaro 2015; Moraci et al. 2018; Zach et al. 2019). This can also provide flexible power and information and communications technologies to support for the operation of critical infrastructure in the post-disaster stage (Alqahtani et al. 2018). The Green University of Tokyo Project promoted by Tokyo, Japan, uses information technology to reduce electricity consumption and carbon emissions, improving urban environment in a smart and intelligent way. The plan connects the air-conditioning, lighting, power supply, safety facilities, and other subsystems in the buildings to form a compatible integrated system and conduct intelligent data analysis to realize intelligent, dynamic, and effective configuration and management of electric energy supply and consumption (Esaki 2021; GUTP 2008).

Sustainable, innovative, and safe transport systems of smart mobility provide infrastructure systems for urban transportation, facilitate integrated transportation networks, help maintain smooth connectivity of roads and communication networks, and restore water or power supply in time (Rus et al. 2018). These series of methods improve the efficiency of transportation system, reduce energy consumption, and improve quality of life. The Urban Transportation Master Plan and Electric Transportation Plan in Vienna, Austria, for example, have addressed problems of traffic congestion and exhaust pollution in urban construction on the one hand and have increased the utilization rate of environmentally friendly transportation and public transportation on the other. The Smart Commuter Initiative proposed by Toronto, Canada, was the first one to integrate advanced technologies such as expressway non-stop electronic toll collection and road traffic information collection to optimize expressway operations and improve transportation efficiency. Implementation of this initiative also improves the operation of traffic management system. Similarly, the highways in Tokyo, Japan, are controlled and monitored by information technology, and restructured information services are provided at any time to avoid various natural disasters and ensure safe operation.

Smart mobility can also adopt information and communications technology infrastructure to provide a basic guarantee for efficient logistics transportation and real-time full-process supervision of commodities and disaster relief medical supplies. The use of diversified contactless takeaway delivery services also provides basic living supplies for people staying at home while ensuring safety (Wen 2020). For example, smart logistics uses the Internet of Things technology to realize the exchange and sharing of information between things in the logistics process. This way, all links of logistics can be tracked and monitored in real time to realize the digitization and information of the entire logistics process, thereby upgrading logistics industry and reducing logistics costs. Moreover, the use of logistics robots can quickly work out the optimal path to increase logistics rate. Further, using blockchain can reduce logistics costs, production, and traceability of goods in transit and improve the efficiency of supply chain management.

5.3.5 Leadership and Strategy

The leadership and strategy of resilient city are assessed by effective leadership and management, empowered stakeholders, and integrated development planning. The smart governance prioritizes effective measures, such as participation in decision-making, transparent governance, and public and social services, to improve leadership and management and facilitate access to up-to-date information and knowledge to enable people and organizations to take appropriate actions. The smart governance dimension is related to the principles of diversity, inclusive (participatory), resourcefulness, equity, and efficiency of cities.

Smart governance employs information and communications technologies to provide government services and exchange information and integrate various independent systems in the face of disasters (Ruhlandt 2018). The intelligent decision-making system, supervision system, and others improve the ‘fineness’ and ‘precision’ of decision-making (Zhou and Fu 2020; Zhu et al. 2019). Through e-government, public government service platforms (e.g., transportation, energy, and water) and government websites have become more service-oriented to provide citizens with consulting information and services to improve the quality of life and satisfaction of citizens. The Wellbeing Toronto Website helps residents to better understand their communities and city government and strengthens the connection and communication between the public and the government. The first-hand public information published on this webpage provides the municipal government with references for relevant resolutions in order to provide public services more in line with the needs of citizens. Smart governance can also assist government managers and medical workers in dynamic management and monitoring through the Internet of Things. For example, the Disease Control AI Analysis Platform (WDCIP) developed by Weizhi Technology is based on related technologies to detect people in close contact, predict the high-risk transmission area of the epidemic, and assist in the analysis of the dynamics of the pandemic's spread. It also provides decision support for relevant government departments and health systems (Yan and Han 2020).

5.4 Challenges and Suggestions for Integrating Smart City and Resilience

Overall, smart city and resilient city have strong connections according to the analysis of the relationships in their assessment indicator systems. Such connections also indicate the potential to integrate smart city and resilient city for sustainable urban development in various aspects such as health and well-being, economy and society, urban system and services, and leadership and strategy. Moreover, the potential integration may promote the efficient and comprehensive operation of society, economy, infrastructure, and management and can enhance the city's redundancy, diversity, and anti-disturbance characteristics.

Within the context of sustainable urban development, there are many opportunities for resilient-smart city development. This has received the support from emerging studies. For instance, the use of emerging big data, cloud computing, and information and communications technology solutions to help cities survive and operate under extreme pressure has been advocated (Palmieri et al. 2016; Soyata et al. 2019; Yang et al. 2017). Urban structures should integrate smart technologies and systems to improve robustness, redundancy, resource richness, and rapidity (Desroches and Taylor 2018). Nevertheless, these studies are only preliminary, and in-depth research, exploration, and testing are needed.

While there are opportunities and possibilities as analyzed in Sect. 5.3, there are a variety of challenges for resilient-smart city development. First, the original goals of smart city and resilient city are different, implying the different requirements in development so that they cannot completely overlap. The elementary focus of a resilient city lies in the urban safety, reflected by the reduction of the casualties and economic losses caused to the city by natural disasters and emergencies and the capabilities of quickly recovering to a normal state after the disaster. In comparison, the focus of a smart city is on the efficient operation of the urban system (Zhu et al. 2020). There could be contradictions between them.

Smart city technology is not a panacea (Boulos et al. 2015), and the introduction of smart technology and thoughts may have negative impacts on resilient city, thereby detracting from urban resilience. First, many defects and shortcomings have been exposed in the application process of smart technologies (Li and Long 2020). If the big data system in smart city fails to collect and analyze key data at high frequency during the emergency period of disasters and make sensitive predictions accurately, it may lead to the collapse of the system. Second, if a city relies too much on smart city technology, in the process of smart city planning, the services are prone to be highly dependent on data and are more susceptible to potential data flow interruptions (Kotevska et al. 2017), also reducing the resilience of infrastructure given security threats (Beck 2017). Third, since the data among different departments cannot be always shared and connected in a timely and effective manner, data conflicts and miscommunications may emerge, making it impossible to efficiently trace the source. For example, for flood prevention and disaster relief, the use of drones and various high-precision sensors has greatly improved the predictability of disaster losses. However, once the data center is paralyzed, it will result in a huge obstacle to continue the work (Beck 2017). Fourth, less consideration has been given to the environment, and social equity and justice (Kaika 2017; Viitanen and Kingston 2014). This is contrary to one of the goals of resilient city (social stability and security) (ARUP 2014). Overall, while the use of smart technology can alleviate environmental problems and emergencies to a certain extent, it is prone to negative effects in terms of data privacy and uncontrolled power relations (Sharifi and Khavarian-Garmsir 2020). For example, for COVID-19 prevention and control, the application of various health codes has greatly improved the efficiency of monitoring and early warning. However, its effectiveness requires a large amount of public identities and travel information gathered by the platforms, which are relevant to public privacy and may lead to multiple risks such as external attacks and internal information leakages (Zhang 2020).

Nevertheless, it is necessary to overcome potential technical and social risks brought by smart city and take the improvement of urban resilience as positive feedback in the smart city development, and build a robust resilient-smart city, so as to manage or solve urban problems and disasters more intelligently, effectively, and accurately. To support this, several suggestions have been provided: (1) development of a comprehensive and systematic resilient-smart city assessment system that incorporates the resilience elements into the smart city assessment system (Song 2020) and strengthen the emergency prediction and sensitive analysis capabilities through big data analytics (Wang and Zhao 2020); (2) improvement of urban resilience as the main direction of smart city development in practice. This requires guiding smart city planning with resilient thinking and promoting resilient-smart city construction with a diversified governance structure. Platforms for urban big data collection and analytics or information centers can ensure seamless data sharing, thereby, offering advantages to technology and data resource organization and providing urban decision-makers with more efficient and accurate support means; (3) enhancement of data privacy and security based on the principle of social fairness. This will require optimizing institutional mechanisms for data development and utilization, strengthening privacy and confidentiality, combining technology-driven and human-driven methods, and enhancing civic awareness to enhance adaptability to future events (Sharifi and Khavarian-Garmsir 2020).

5.5 Conclusions

Combination of the concepts of smart city and resilient city to develop resilient-smart cities is drawing increasing attention for and accelerating sustainable urban development under a variety of mega challenges of climate change, urbanization, environmental deterioration, unbridled economic growth, and population growth. This chapter advances the theoretical understanding of the concept of resilient-smart city through exploring the possibilities of the integration of smart city and resilient city concepts. In particular, the possibilities were evidenced through analyzing the connections between the six components of smart city, namely governance, people, life, mobility, economy, and environment and the four components of resilient city, namely health and well-being, economy and society, infrastructure and ecosystems, and leadership and strategy. In the resilient-smart city framework, smart city solutions and technologies provide technical support to ensure a resilient city can deal with disasters and emergencies in an efficient manner, while the resilient city provides positive feedback for smart city in resisting external interferences and disturbances. Nevertheless, information accuracy, data security, data sharing, and associated social equity and justice issues are challenges a smart city can generate when being integrated into resilient city systems. To overcome such challenges, this chapter also presented suggestions to be considered in the development of resilient-smart city assessment system, the improvement of resilience of smart city, and the enhancement of social issues in smart technology utilization. Overall, this chapter is expected to provide scholars and practitioners with a point of reference regarding the principles and characteristics of resilient-smart city. This, in turn, is expected to lead to better recognitions of resilient-smart city in academia and practice.

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