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Smart city indicators: Towards exploring potential linkages to disaster resilience abilities

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ABSTRACT

Recent advances in Information and Communication Technologies (ICTs) have transformed all aspects of human life. Enabled by these advances, over the past few decades, many smart city initiatives have been developed across the world. Subsequently, various efforts have been made to develop indicators and frameworks for the assessment of smart cities. Generally, smart cities are expected to enhance the quality of life and provide solutions to deal with societal challenges. One major societal challenge is the increase in the frequency and intensity of disasters and adverse events. Therefore, smart cities are expected to contribute to enhancing disaster resilience. Integrating resilience thinking into smart city indicators and assessment frameworks is likely to promote better attention to the resilience contributions of smart cities. Against this background, through reviewing the literature, I first introduce a comprehensive list of indicators for assessing city smartness. Multiple indicators related to economy, people, governance, environment, mobility, living and data dimensions of a smart city are listed. Next, I explore if these indicators are aligned with the four resilience abilities: planning, absorption, recovery, and adaptation. Results show that smart city indicators are particularly linked to planning and absorption abilities. More attention to the recovery and adaptation abilities is, therefore, needed.

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KEYWORDS

Smart city, disaster resilience, indicators, urban, disasters, assessment tools, index

HIGHLIGHTS

- Smart cities have increasingly become ubiquitous.
- Smart cities should contribute to enhancing community resilience.
- A comprehensive list of indicators for smart city assessment is introduced.
- Resilience thinking is not fully integrated into smart city indicators.
- A framework to integrate resilience thinking into smart city assessment is proposed.

1. INTRODUCTION

We now live in the age of digital revolution, and digital technologies have transformed almost every aspect of our lives. As cities have historically been centres of innovation, it is no surprise that they are now at the forefront of developing and implementing digital technologies. In fact, many cities around the globe are increasingly relying on digital technologies, enabled by Information and Communication Technologies (ICTs), to overcome societal challenges, enhance the quality of life, and improve the efficiency and efficacy of urban operations (Ahvenniemi, Huovila, Pinto-Seppa, & Airaksinen, 2017; Clarke, 2013; Kourtit & Nijkamp, 2018; Woods, Labastida, Citron, Chow, & Leuschner, 2017). The ICT-enabled efforts and activities are often referred to as smart city movements.

The smart city concept emerged in the early 2000s and has gradually evolved over the past two decades. During this period, many smart city projects and initiatives have been developed, and this trend is expected to continue further in the coming decades (Angelidou, 2015; Caragliu, Del Bo, & Nijkamp, 2011; Marsal-Llacuna, Colomer-Llinas, & Melendez-Frigola, 2015). This increasing interest in smart cities is not surprising given their multiple utilities. For instance, it is now widely believed that becoming smart is critical to maintaining a competitive advantage in an increasingly connected world (Giffinger et al., 2007; Giffinger, Haindlmaier, & Kramar, 2010). Related to this, smarter cities are likely to be in a better position to attract talented and creative citizens capable of contributing to local economy and growth through promoting innovative and efficient approaches (Angelidou, 2015; BSI, 2014). Furthermore, ICT-enabled smart solutions are expected to contribute to enhancing the urban quality of life, enhance the transparency of urban management, and help overcome some long-standing challenges related to urban inequalities, ageing society, and safety and security (BSI, 2014; Manville et. al., 2014).

Related to the focus of this paper, smart cities are also expected to provide solutions for dealing with a major societal challenge: the increase in the frequency and intensity of disastrous events. These include events related to climate change, as well as natural disasters such as earthquakes and man-made events such as nuclear events (Huovila, Airaksinen, Pinto-Seppä, Piira, & Penttinen, 2016). This is motivated by the fact that an increasing trend in the annual frequency of climate-induced, natural, and human-made disasters can be observed from the analysis of loss events in the past few decades (Hoeppe, 2016; Smith & Katz, 2013). For instance, as a clear sign of global warming, the last six years have been the warmest on record since 1850 and last year was the warmest (World Meteorological Organization, 2020). Extreme heat and multiple other adverse events, cumulatively, result in billions of dollars of economic loss in cities that are often more vulnerable due to their higher concentration of humans and resources.

According to some estimates, every year, about USD 300 billion is lost to disasters in cities and,

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unless cities build on their resilience, economic losses to disasters in cities may cross USD 400 billion by 2030 (Word Bank, 2016). Given these threats and challenges, it is clear that one major contribution of smart city solutions, technologies, and projects should be enhancing disaster resilience. Here, resilience refers to the "ability to plan and prepare for, absorb, recover from, and more successfully adapt to adverse events" (Cutter et al., 2013). Resilience is also characterized by multiple attributes such as robustness, stability, diversity, redundancy, resourcefulness, creativity, agility, flexibility, efficiency, self-organization, inclusiveness, and foresight capacity (Sharifi & Yamagata, 2016).

In planning and policymaking circles, assessment is widely recognized as an effective method for improving the performance of projects, and policies and smart city projects and policies are no exception (Sharifi, 2020). Indeed, assessment can provide useful insights to municipal authorities, smart city developers and investors, and the public (Caird & Hallett, 2018; Mohan, Dubey, Ahmed, & Sidhu, 2017). For instance, it can facilitate regular performance monitoring, highlight strengths and weaknesses, track progress towards targets and goals, identify technical requirements and economic feasibility issues, showcase best practice cases, encourage constructive competition through benchmarking, enhance governance transparency, raise general awareness, and provide engagement motivations (Caird & Hallett, 2018; Mohan et al., 2017). Given these multiple utilities of assessment frameworks, it is essential to ensure that they are well-designed and capable of addressing the capacity to deal with societal challenges.

Against this backdrop, the main objectives of this study are to provide a list of indicators that have been used for smart city assessment and to explore their potential contributions to the four resilience abilities, namely, planning/preparation, absorption, recovery, and adaptation. In other words, it aims to examine if smart city indicators are aligned with resilience abilities. Planning refers to the ability to take preparatory measures before the occurrence of a shock to better deal with possible disasters. Absorption indicates the ability to minimize functionality loss and associated socio-economic damages. Recovery refers to the ability to return to pre-shock conditions in a timely manner. Finally, adaptation indicates the ability to learn from the adverse event to not only bounce back but also bounce forward. The paper is structured as follows. The methods are described in the next section. Section 3 provides the list of indicators and discusses how resilience thinking can be integrated into smart city indicators. Finally, section 4 concludes the study by summarizing the results and providing recommendations.

2. METHODOLOGY

Content analysis of smart cities literature is the main method used for developing a comprehensive list of smart city indicators and classifying them into several categories. First, I searched for relevant documents in the Web of Science using combinations of terms related to smart cities and assessment. For this purpose, the following broad-based search string was used:

TS=(((“certificat*” NEAR/1 (“tool*” OR “toolkit*” OR “system*” OR “indicator*” OR “framework*” OR “index” OR “scorecard*” OR “scheme*”)) OR (“evaluat*” NEAR/1 (“tool*” OR “toolkit*” OR “system*” OR “indicator*” OR “framework*” OR “index” OR “scorecard*” OR “scheme*”)) OR (“assess*” NEAR/1 (“tool*” OR “toolkit*” OR “system*” OR “framework*” OR “indicator*” OR “index” OR “scorecard*” OR “scheme*”)) OR (“measur*” NEAR/1 (“tool*” OR “toolkit*” OR “system*” OR “framework*” OR “indicator*” OR “index” OR “scorecard*” OR “scheme*”))) AND (“smart”) AND ((“city” OR “cities” OR “communities” OR “community” OR “neighbo*rhood*” OR “district*”))) (Sharifi, 2020). Documents retrieved using this string were screened, and 58 articles were selected for final analysis (Sharifi, 2019). In addition, I did a Google search to find potentially relevant grey literature that can be used for extracting indicators. After downloading the documents, the inductive content

analysis method was used to extract the list of indicators (Mayring, 2014). An inductive content analysis data collection and analysis are conducted simultaneously (Mayring, 2014). In this case, this means that as the first document was reviewed, relevant indicators were added to the list. When reading the next document, it was checked whether the mentioned indicators fall under the previously listed indicators or should be added as new ones. This process was continued for all the documents, and, based on the results, a complete list of indicators was developed that will be presented in the next section. While doing the content analysis, I also noted major smartness dimensions mentioned in the literature. These were economy, people, governance, environment, mobility, living, and data (Sharifi, 2020). In the end, the extracted indicators were assigned to the smartness dimensions. This was done based on the author's discretion and, therefore, involves some form of subjective judgment. To explore links between the indicators and resilience, each indicator's relevance to different resilience abilities was examined, and a synthesis table was developed. More specifically, based on the literature and the author's opinion, it was determined if each indicator contributes to the four resilience abilities (planning, absorption, recovery, and adaptation). This was determined based on yes/no questions. For each theme, depending on the percentage of indicators linked to each resilience ability, its extent of alignment with the resilience abilities was determined.

3. RESULTS AND DISCUSSION

In this section, I first present the list of indicators related to economy, people, governance, environment, mobility, living and data. Next, I discuss an approach for integrating resilience thinking into smart city assessment.

3.1 Smart city indicators

In each of the following subsections, indicators related to the seven major smart city dimensions will be presented.

3.1.1 Economy

Many indicators related to the economy were identified, which is not surprising considering that, as mentioned earlier, one of the major objectives of smart city initiatives is to strengthen the position of cities in an increasingly competitive global economy. These indicators are divided into major themes: innovation, knowledge economy, entrepreneurship, finance, tourism, employment, local & global interconnectedness, productivity, the flexibility of the labour market, and impacts (Table 1).

Theme	Indicator
Innovation	R&D expenditure (% of GDP)
	Policies, programs, and plans for promoting creativity/innovation
	Patent applications/registration per inhabitant
	The competitive position of the city in terms of science and engineering centres
	ICT-enabled innovation leading to new businesses and market opportunities
Knowledge economy	Green economy
	Share of public/private investment in smart industries
	Rate of import-export related to smart industry and knowledge-intensive economy
	Industry-academia-government cooperation
	Contribution of knowledge economy and ICT initiatives to GDP (%)
	Space for knowledge exchange and business promotion
	Share of e-business and e-commerce transactions
Entrepreneurship	Policies, programs, and plans for promoting entrepreneurship
	Self-employment rate
	Small and Medium Enterprises trends

TABLE 1. Economic indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi, Kawakubo, & Milovidova, 2020.

Theme	Indicator
	Number of start-ups
	Promotion of start-up companies
	Number of businesses and new businesses registered annually
Finance	Funding for smart city projects (public/private finance, crowdsourced, etc.)
	Consideration of market demands and needs in smart city planning
	Total market value of commercial and industrial properties
	Financial stability (e.g., city and per capita reserves, city's debt service ratio)
	Global/regional competitiveness in attracting companies with low sales taxes
	Tax collected as a percentage of tax billed
Tourism	Importance as a tourist hub
	Affordability and accessibility as a tourist destination
	Tourism impact management
	Online and ICT-enabled tourism promotion
Employment	City's employment/unemployment rate, measures to combat unemployment
	Availability of labour force, working-age population
	Local employment opportunities
	Employment rate improved by smart solutions
	Rate of employment in tourism industry
	Rate of employment in knowledge-intensive sectors/ creative industry
Local & Global Interconnectedness	Gross regional product per capita (GRP)
	Procurement style
	Presence of major international and domestic enterprises and entities in the city
	City internationalization activities
	Cross-city smart city initiatives and collaboration
	Importance on the national and regional scale
	Adoption of International Organization for Standardization
	Using ICT measures for improving domestic and international communication and cooperation
Productivity	GDP per employed person
	Primary, secondary, and tertiary industry's share of GDP
	ICT measures to improve industry/economic/employee productivity
	Plans and strategies for economic development
	Foreign direct investment and inward investment
	Cost-benefit analysis
Flexibility of the labour market	Measures to improve accessibility to labour market
	ICT-enabled flexibility and improvement of traditional industry and job market
	Home-based work and workspace flexibilization
	Timetable flexibilization
	Perception of getting a new job; flexibility of the workforce
Impacts	Costs of development, operation, and maintenance of smart city projects
	Economic impacts of smart city initiatives
	Plans for management of risks

TABLE 1 continued. Economic indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

3.1.2 People

People are the main users of smart city solutions and technologies. In addition, as major stakeholders, they can contribute to the enhanced design and development of smart cities. Indicators related to people and their capacities are related to education, ICT skills and open-mindedness (Table 2).

3.1.3 Governance

Integrated governance mechanisms are critical to ensure the efficacy and efficiency of smart city solutions and technologies. As Table 3 shows, governance indicators are related to themes such as visioning and leadership, legal frameworks, participation, transparency, public services, and integrated management.

Theme	Indicator
Education	Importance as a knowledge hub
	Percentage of the population working in higher education and R&D sector
	Update and adjustment of educational facilities, curricula, and material to improve digital skills
	Measures to improve quality of educational infrastructure
	Adult literacy trends
	Availability and penetration of e-learning and distance education systems
	Application of ICT technology, analytics platforms, and e-learning
	IT training and raising awareness about smart city benefits
	Student/teacher ratio
Level of qualification/ ICT skills	Percentage of population with secondary-level education
	Percentage of population with tertiary-level education
	Foreign language skills of the citizens
	Individual-level of computer skills
	Internet penetration (netizen ratio)
	Social networking penetration
	Level of digital and ICT literacy and technical capability
Open-mindedness	Inhabitants' attitude towards international treaties
	Share of foreigners and nationals born abroad
	Use of ICT measures to create an immigrant-friendly environment

TABLE 2. People indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
Visioning and leadership	Clear and inclusive digital strategy and smart city vision
	Smart city roadmap
	Historical experience of technology development
	A broad-based leadership team that features appropriate mix of skills
	Sustained leadership commitment to long-term smart city programs
	Strong Leadership
	Plans and strategies for mainstreaming smart city planning
	Plans and strategies for performance monitoring and assessment
	Availability of risk governance plans and strategies and using smart solutions

TABLE 3. Governance indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
Legal frameworks	Laws and regulations for smart city planning
	Strategies to overcome organizational, legal and regulatory barriers
	Legal and regulatory frameworks to protect consumer privacy
Participation	Democracy, individual freedom, freedom of media, speech, etc.
	Extent of involvement of local authority/city administration in smart solution programs
	Public participation and stakeholder engagement in decision making
	Political activity of inhabitants
	ICT-enabled participation in bottom-up voluntary work/service
	Online civic engagement and feedback system
	Dynamic interconnection with citizens, communities, and businesses
	Collaborative service production and delivery
Transparency	Governmental transparency
	Leadership accountability
	Mapping skills and transparent division of responsibilities between different actors
	Bureaucracy status
	Corruption index and measures to fight corruption
Public services	Digitalization of governance and public expenditure on ICT and smart city transition
	One-stop platform for data integration and for online accessibility and coordination of city services
	Presence of people and public entities in social networks/media
	Penetration rate of online government service
	Presence of electronic and mobile payment platforms
Integrated management	Interoperability between urban systems and subsystems
	The state of data/information sharing among various institutions
	Shared architecture for multi-level governance and inter-agency collaboration
	Cross-agency coordination for integrated infrastructure management
	Public-private partnership
	Efficiency in the provision of services
	Appropriate balance of top-down and bottom-up governance processes
	Cross-city engagements and collaborations for knowledge exchange

TABLE 3 continued. Governance indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

3.1.4 Environment

Smart cities can provide solutions to promote environmentally friendly cities. However, it is also essential to take measures to minimize their own environmental footprint. This dimension focuses on issues such as environmental monitoring, infrastructure, built environment, materials, energy, water, waste and environmental quality (Table 4).

3.1.5 Living

One of the major goals of smart cities is to enhance the quality of life of citizens. This dimension focusses on issues such as social cohesion, justice, culture, housing quality, healthcare, safety and security and subjective well-being (Table 5).

3.1.6 Mobility and communication

Mobility and communication are major sectors that have adopted smart technologies. Indicators used to assess the smartness of mobility are related to transport infrastructure and management, ICT infrastructure and management, and ICT accessibility (Table 6).

Theme	Indicator
Environmental monitoring	Sustainable natural resource management
	(ICT-enabled) environmental monitoring infrastructure
	Environmental/ecosystem protection activities
	(ICT-enabled) activities to disseminate environmental quality information
	Life cycle impacts of ICT infrastructure and smart cities
	Citizen involvement in resource management
	Availability and implementation of climate resilience plans/strategies
General infrastructure	Availability of basic critical infrastructure
	Decentralized and modular (autonomous) infrastructure systems
	Green infrastructure and green city initiatives
	Penetration level of energy-saving technologies
	Use of integrated smart management, operation, and monitoring systems
	Local food production
Built environment	Urban sprawl containment
	Mixed-use development
	Area of green/blue space
	Preservation of historic buildings
	Ambitiousness of building energy efficiency standards
	Building Information System
	ICT-enabled urban planning
Materials	Efficiency of material consumption
	Share of recycled and renewable materials used in projects
Energy resources	Energy management plans and policies
	Total energy consumption
	Penetration of clean and renewable energy sources
	Efficient management and use of energy
	Greenhouse gas emission intensity of energy consumption
	Smart grids
	Using ICT measures for management, monitoring and saving of energy
	Reliability and quality of electricity supply
Water resources	Water management plans and policies
	Quality of water resources and water bodies, quality monitoring
	Efficient generation, distribution, and use of water
	Total annual water consumption
	Water loss monitoring and reduction
	Water energy consumption
	Use of smart water meters
	Using ICT measures for management, monitoring, and saving of water
	Reliability
Waste	Waste management plans and policies
	Efficient and smart solid waste collection
	Total per capita municipal waste
	Proportion of recycled waste

TABLE 4. Environment indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
	Energy production from waste and wastewater
	Sewage and wastewater management and treatment/recycling
	Drainage system management, stormwater management
	Using ICT measures such as smart sensors for management of solid waste
Environmental quality	Air quality index/ pollution concentration levels
	Per capita GHG emissions
	Water pollution index; reduce water contamination
	Soil pollution
	Noise pollution

TABLE 4 continued. Environment indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
Social cohesion	Community cohesion
	Demographic structure
	Trust and norms of reciprocity
	Diversity and measures for promoting diversity
	Volunteer activities and civic engagement in social networks
	Universal design of the physical environment and ICT services
	Using ICT for promoting community connectivity and mutual support
Justice	Income level
	Ethnic, cultural, and gender equality
	Protection of human rights
	Physical access to amenities
	Affordable, authorized and sustainable access to services and utilities
	Enhancement in affordability and accessibility to services
Culture	Percentage of municipal/individual budget allocated to culture
	Cultural infrastructure
	Size and quality of community centres
	Use of ICT for promotion of culture
	Protection and management of cultural heritage
Housing quality	Cost of living
	Housing quality
	Housing expenditure
Healthcare	Healthcare expenditure
	Health insurance coverage
	Healthcare services and infrastructure per capita
	General well-being
	Childcare system, daycare services for children
	Healthcare for elderly; well-being of seniors
	Use of ICT and smart technologies for promoting well-being
	Use of ICT for trace-back monitoring of food and drugs
	Percentage of citizens archiving electronic health records

TABLE 5. Living indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
	Sharing rate of records, information, and resources among clinics
	Adoption of telemedicine
Safety and security	Disaster risk planning, monitoring, and management
	Response time for police and emergency departments
	Use of ICT for disaster prevention and prediction
	Disaster-related economic losses
	Individual safety and security
	Community safety and crime rate
	Using technology and ICT for crime prediction, prevention and control
	Crime reduction rate attributable to ICT usage
Subjective well-being	Satisfaction (perception of) with quality of life
	ICT-enabled increase in employee satisfaction

TABLE 5 continued. Living indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
Transport infrastructure	Green transportation modes
	Number of EV charging stations in the city
	Autonomous Vehicle (AV) testing and deployment
	Public transport system and its quality, diversity, and multi-modality
	Private car ownership rate
	Car and bike-sharing services
	Cycling infrastructure options and facilities
	Pedestrian environment and walking options
	Street/pedestrian area smart/automatic lighting management system
Transportation management	Strategic transportation network management
	Travel distance
	Share of total trips made by active /public transport modes
	Performance, safety, and efficiency of public transportation
	Real-time information about transit services and parking
	Road traffic efficiency
	Road safety, rate of traffic accidents
	ICT-enabled transportation damage and fatalities reduction
	Private car traffic restriction
	Sensing and monitoring for real-time, smart and automated traffic management
	Trackability and traceability of goods and vehicles
	Smart pricing, smart price policies, demand-based pricing
ICT infrastructure	Availability of IT and digital infrastructure
	Broadband internet
	Maintenance and regular revision of the ICT infrastructure
	Integrated platform for real-time smart city operation and management
	Fixed phone (landline) and mobile phone network coverage

TABLE 6. Mobility indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
	Rate of coverage by mobile broadband (3G, 4G, 5G)
	Availability of apps
	Availability of smart computing technologies and platforms
ICT management	Quality of internet service
	Information privacy and security management
	Existence of systems and regulations to ensure child online protection
	Application of cloud computing services
	Diversity of booking/payment options
	Integrated fare/payment system for inter-service digital fare collection capability
ICT accessibility	Physical accessibility of IT infrastructure
	Socio-economic accessibility to digital technologies
	Per-capita public/private ICT expenditure
	Fixed and wireless broadband subscriptions
	Personal computer/laptop/tablet ownership rate
	Smartphone penetration
	Free Wi-Fi coverage in public spaces

TABLE 6 continued. Mobility indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

Theme	Indicator
Data openness	Availability and publication of data in an open format
	Open data platforms for making information open to the public
	The user-friendliness of the open data platform/portal
	Data platforms that are linked to each other
Sensing and collecting	Infrastructure, systems, and strategies for data collection
	Strategies and infrastructure for autonomous real-time sensing of data
	Citizen participation in collecting real-time data and using them
	Infrastructure for storing and structuring data
	Systems, strategies, protocols, and infrastructure for timely data communication
Judging (analytics)	Data quality management
	Strategies, tools, and infrastructure for data filtering and classification
	Systems, strategies, protocols, tools and infrastructure for data analytics
	Strategies, tools, and infrastructure to evaluate data and use it for making predictions
Reacting	Government decision-making based on data and evidence
	Enterprise decision making
	Citizen decision making
Learning	Mode upgrading
	Process upgrading
	Experience upgrading

TABLE 7. Data indicators. Adapted from Sharifi, 2019; Sharifi, 2020; and Sharifi et al., 2020.

3.1.7 *Data*

Data is the cornerstone of smart city projects. Indicators belonging to this dimension cover issues such as data openness, data collection, data analytics, data use, and learning (Table 7).

3.2 Links between the indicators and disaster resilience

As mentioned earlier, in this study, resilience is defined as the ability to plan and prepare for, absorb, recover from, and adapt to adverse events (four abilities). To determine if the smart city indicators can contribute to resilience, their potential to contribute to each of the four abilities was examined. The synthesis results are shown in Table 8. More elaboration on how each theme is linked to resilience abilities is beyond the scope of this study. Interested readers are referred to Sharifi and Allam (2022) for more information. This table shows the extent of relevance of indicators related to each theme to resilience abilities (in %). As can be seen, the highest linkages to resilience abilities are to planning and absorption with 63% and 58%, respectively.

In contrast, only 34% and 25% are related to adaptation and recovery, respectively. Overall, these results show that smartness assessment indicators can, to some extent, also be used to evaluate the resilience abilities of cities and projects. There is clearly limited attention to recovery and adaptation abilities. Further research is needed to understand better why those abilities have not been well accounted for. One possible reason could be that the concepts of smart city and resilience city are relatively new and have often been undertaken in isolation from one another. More integrated approaches towards them are likely to help solve this issue.

Theme	Planning (%)	Absorption (%)	Recovery (%)	Adaptation (%)
Innovation	100	0	20	80
Knowledge economy	71	29	14	57
Entrepreneurship	50	67	33	67
Finance	50	50	33	33
Tourism	50	100	25	25
Employment	67	100	50	0
Local & Global Interconnectedness	14	86	86	0
Productivity and efficiency	43	71	57	14
Flexibility of the labor market	20	100	0	80
Impacts	100	33	0	0
Education/ lifelong learning	100	22	0	44
Level of qualification	100	43	29	0
Cosmopolitanism	33	33	0	100
Visioning and leadership	100	0	22	44
Legal and regulatory frameworks	100	0	0	100
Participation	100	0	86	29
Transparency	100	0	100	0
Public and social services	60	80	0	60
Efficient and integrated management	75	50	63	13
Environmental monitoring	71	71	14	43
General infrastructure	50	83	17	33

TABLE 8. Links between the themes and resilience abilities.

Theme	Planning (%)	Absorption (%)	Recovery (%)	Adaptation (%)
Built environment/	29	57	57	57
Materials	0	100	0	100
Energy	50	88	13	50
Water	33	78	11	67
Waste	25	100	0	75
Environmental quality	100	20	0	0
Social cohesion	43	71	86	0
Justice	33	67	83	0
Culture	60	80	40	0
Housing quality	33	100	67	0
Healthcare	18	91	55	36
Safety and security	38	100	0	0
Convenience and satisfaction	100	0	0	0
Transport infrastructure	33	78	0	89
Transportation management	58	92	0	100
ICT infrastructure	75	75	25	0
ICT management	83	67	0	17
ICT accessibility	100	100	0	0
Data openness	100	50	0	0
Sensing and collecting	100	80	20	0
Analytics	100	25	0	0
Reacting	100	0	0	0
Learning	0	0	0	100
Average	63	58	25	34

TABLE 8 continued. Links between the themes and resilience abilities.

4. CONCLUSION

Smart city initiatives, enabled by ICTs, have become ubiquitous in the past few years. By developing smart cities, planners and policymakers hope to, among other things, enhance the quality of life, improve the efficacy and efficiency of urban management, and provide solutions for complex societal challenges, such as the increase in the frequency and intensity of disasters. Assessment is argued to be an effective method to mainstream smart city principles into decision- and policy-making processes and to ensure achievement of the smart city objectives.

The main objectives of this study were to provide a comprehensive list of indicators that can be used for smart city assessment and to examine their potential linkages to four resilience abilities: planning/preparation, absorption, recovery and adaptation. The results show that smartness is a multi-dimensional concept and is beyond just technological development. Multiple indicators were introduced that are divided into seven major dimensions: economy, people, governance, environment, living, mobility and data. Obviously, achieving smartness is a challenging ambition and requires concerted efforts across multiple sectors and dimensions. As for operationalizing the introduced assessment framework, it should be noted that using a large list of indicators would not be realistic in most cases due to resource limitations. Therefore, it is suggested that interested stakeholders would consider the suggested list as a pool of indicators and select those that are relevant and context-specific. Some statistical methods, such

as principal component analysis, can also be used to establish a more concise and manageable list of indicators.

As for connections to resilience, it was found that smart city indicators are linked to resilience abilities, particularly abilities to plan/prepare for and absorb shocks. This is not surprising as, for instance, early warning capacities facilitated by real-time monitoring and big data analytics can allow cities to better respond to shocks. However, results show that recovery and adaptation abilities are not well accounted for. It was suggested that this could be due to, often, isolated approaches to smartness and resilience. Adopting more integrated approaches is needed to achieve better alignment between smartness indicators and resilience abilities. Further dimension-specific research is needed to better understand through what specific mechanisms smart city indicators can inform resilience-oriented urban planning and management. As resilience is also characterized by multiple attributes such as robustness, stability, diversity, redundancy, resourcefulness, creativity, agility, flexibility, efficiency, self-organization, inclusiveness and foresight capacity, future research should also explore potential connections of smart city indicators to these attributes.

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REFERENCES

Ahvenniemi, H., Huovila, A., Pinto-Seppa, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities, 60*, 234-245. doi:10.1016/j.cities.2016.09.009

Angelidou, M. (2015). Smart cities: A conjuncture of four forces. *Cities, 47*, 95-106. doi:10.1016/j.cities.2015.05.004

BSI. (2014). *Smart city framework – Guide to establishing strategies for smart cities and communities*.

Caird, S. P., & Hallett, S. H. (2018). Towards evaluation design for smart city development. *Journal of urban design*, 1-22. doi:10.1080/13574809.2018.1469402

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart Cities in Europe. *Journal of Urban Technology, 18*(2), 65-82. doi:10.1080/10630732.2011.601117

Clarke, R. (2013). *Business Strategy: IDC Government Insights' Smart City Maturity Model—Assessment and Action on the Path to Maturity*. International Data Corporation (IDC) Government Insights, Business Strategy# GI240620. Alexandria, VA: USA.

Cutter, S. L., Ahearn, J. A., Amadei, B., Crawford, P., Eide, E. A., Galloway, G. E., . . . Zoback, M. L. (2013). Disaster Resilience: A National Imperative. *Environment: Science and Policy for Sustainable Development, 55*(2), 25-29. doi:10.1080/00139157.2013.768076

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., & Meijers, E. (2007). *Smart cities: Ranking of European medium-sized cities.* Vienna, Austria: Centre of Regional Science (SRF), Vienna University of Technology. Retrieved from http://www.smart-cities.eu/download/smart_cities_final_report.pdf

Giffinger, R., Haindlmaier, G., & Kramar, H. (2010). The role of rankings in growing city competition. *Urban Research & Practice, 3*(3), 299-312. doi:10.1080/17535069.2010.524420

Hoeppe, P. (2016). Trends in weather related disasters – Consequences for insurers and society. *Weather and Climate Extremes, 11*, 70-79. doi:10.1016/j.wace.2015.10.002

Huovila, A., Airaksinen, M., Pinto-Seppä, I., Piira, I., & Penttinen, T. (2016). Smart city performance measurement system. Paper presented at the 41st IAHS World Congress on Housing: Sustainability and Innovation for the Future, IAHS 2016.

Kourtit, K., & Nijkamp, P. (2018). Big data dashboards as smart decision support tools for i-cities – An experiment on stockholm. *Land Use Policy, 71*, 24-35. doi:10.1016/j.landusepol.2017.10.019

Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J. K., Thaarup, R. K., . . . Kotterink, B. (2014). *Mapping smart cities in the EU.*

Marsal-Llacuna, M. L., Colomer-Llinas, J., & Melendez-Frigola, J. (2015). Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. *Technological Forecasting and Social Change, 90*, 611-622. doi:10.1016/j.techfore.2014.01.012

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution*. Retrieved from https://www.ssoar.info/ssoar/bitstream/handle/document/39517/ssoar-2014-mayring-Qualitative_content_analysis_theoretical_foundation.pdf.

Mohan, A., Dubey, G., Ahmed, F., & Sidhu, A. (2017). *Smart*

Cities Index: A tool for evaluating cities.

Sharifi, A. (2019). A critical review of selected smart city assessment tools and indicator sets. *Journal of Cleaner Production, 233*, 1269-1283. doi:10.1016/j.jclepro.2019.06.172

Sharifi, A. (2020). A typology of smart city assessment tools and indicator sets. *Sustainable Cities and Society, 53*, 101936. doi:10.1016/j.scs.2019.101936

Sharifi, A., & Yamagata, Y. (2016). Principles and criteria for assessing urban energy resilience: A literature review. *Renewable and Sustainable Energy Reviews, 60*, 1654-1677. doi:10.1016/j.rser.2016.03.028

Sharifi, A., Kawakubo, S., & Milovidova, A. (2020). Urban sustainability assessment tools: toward integrating smart city indicators. In Y. Yamagata & P. P. J. Yang (Eds.), *Urban Systems Design* (pp. 345-372). Elsevier. doi:10.1016/B978-0-12-816055-8.00011-7

Sharifi, A., & Allam, Z. (2022). On the taxonomy of smart city indicators and their alignment with sustainability and resilience. *Environment and Planning B: Urban Analytics and City Science, 49*(5), 1536–1555. doi:10.1177/23998083211058798

Smith, A. B., & Katz, R. W. (2013). US billion-dollar weather and climate disasters: data sources, trends, accuracy and biases. *Natural Hazards, 67*(2), 387-410. doi:10.1007/s11069-013-0566-5

World Bank. (2016). *Investing in Urban Resilience: Protecting and Promoting Development in a Changing World*. Washington, DC: World Bank.

World Meteorological Organization. (2020). *State of the Global Climate 2020: Provisional Report*. World Meteorological Organization. Retrieved from https://library.wmo.int/doc_num.php?explnum_id=10444.

Woods, E., Labastida, R. R., Citron, R., Chow, T., & Leuschner, P. (2017). *UK Smart Cities Index 2017: Assessment of Strategy and Execution for the UK's Leading Smart Cities.*