Capitalizing on Smart City Practices in Optimizing Urban Resilience:

Fresh Perspective from Amman City in Jordan

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Abstract:

Despite the widely recognized key role of smart city practices in optimizing cities' capacities to predict disasters and unexpected shocks, their contribution to enabling urban resilience remains unclear. In this context, the aim of this study to explore the role of smart city practices in improving urban resilience in Amman, Jordan. To this end, we developed an assessment framework consisting of six dimensions of smart city and 13 capacities of urban resilience, totaling 68 indicators. Regression results reveal that Amman has made significant progress in enhancing urban resilience through smart solutions across various domains, including the smart environment, smart economy, smart governance, smart living, and smart people. However, the contribution of smart mobility to urban resilience is limited compared to other domains. Based on these findings, this study offers important insights for policymakers and researchers seeking to strengthen the link between smart city practices and urban resilience, ultimately promoting urban resilience.

Keywords: Urban Resilience; Smart City Practices; Sustainable Development; Disasters and Shocks; Amman; Jordan

ملخص:

على الرغم من الدور الرئيسي المتعارف عليه على نطاق واسع لممارسات المدن الذكية في تحسين قدرات المدن على التنبؤ بالكوارث والصدمات غير المتوقعة، إلا أن مساهمتها في تمكين المنعة الحضرية لا تزال غير واضحة. في هذا السياق، تهدف هذه الدراسة إلى استكشاف دور ممارسات المدن الذكية في تحسين المنعة الحضرية في عمّان، الأردن. ولتحقيق هذه الغاية، قمنا بتطوير إطار تقييمي يتكون من ستة أبعاد للمدينة الذكية و١٣ قدرة للمنعة الحضرية، بإجمالي ٦٨ مؤشرًا. تكشف نتائج الانحدار أن عمّان قد أحرزت تقدمًا كبيرًا في تعزيز المنعة الحضرية من خلال حلول ذكية في مختلف المجالات، بما في ذلك البيئة الذكية، والاقتصاد الذكي، والحوكمة الذكية، والحياة الذكية، والأشخاص الأذكياء. ومع ذلك، فإن مساهمة التنقل الذكي في المنعة الحضرية محدودة مقارنة بالمجالات الأخرى. بناءً على هذه النتائج، تقدم هذه الدراسة رؤى مهمة لصانعي السياسات والباحثين الذين يسعون إلى تعزيز الصلة بين ممارسات المدن الذكية والمنعة الحضرية، مما يعزز في نهاية المطاف المنعة الحضرية.

الكلمات المفتاحية: المنعة الحضرية؛ ممارسات المدن الذكية؛ التنمية المستدامة؛ الكوارث والصدمات؛ عمّان؛ الأردن

1. Introduction

Cities are complex systems of physical and human components [1,2,3,4]. Nonetheless, they are highly vulnerable when any of their systems are unable to absorb unexpected shocks, which can lead to severe crises [5]. Unexpected shocks, such as natural disasters, wars, epidemics and diseases, pollution, famines, and terrorist attacks, among others, contribute to declining urban environments [6]. Although these risks continue around the world, their effects vary from city to city due to differences in ecological, social, and economic systems that respond to these shocks across countries [7]. According to the United Nations Economic and Social Commission for Asia and the Pacific [8], around 60% of global disasters occur in Asian and Pacific countries, which also face the highest proportion of economic losses. Several cities have experienced crises and have been able to withstand them, such as Berlin, Hiroshima, Beirut, Agadir, and Warsaw. Hence, the ability of an urban system and all its social, economic, technological, and ecological subsystems to maintain or rapidly return to required functions in the face of shocks [9,10] plays a critical role in determining the efficiency of urban resilience.

Recently, information and communication technologies (ICTs) have become essential instruments for enhancing the capacities of urban systems, as they enable effective responses to unexpected disasters and shocks [11,12,13,14]. Jiang et al. [15] argue that technology, knowledge, intelligence, and innovation are crucial drivers for improving urban performance to meet disasters and shocks. Similarly, Meerow et al. [10] and Ribeiro and Gonçalves [16] confirmed that a city's ability to withstand disasters while maintaining its essential functions and structures is influenced highly by smart city practices. Thus, smart city practices are essential for enhancing urban resilience. Various models have been created to explore the relationship between

information technology and urban resilience, such as the Smart City Wheel (SCW) developed by Cohen and the City Resilience Index (CRI) established by the Rockefeller Foundation [12]. These models offer a wide range urban indicators, highlighting the connection between smart city practices and urban resilience [17]. Several researchers (e.g., [18,19,20]) have shown how smart infrastructure can help cities withstand shocks and crises while enhancing resilience. However, these studies have not thoroughly addressed the various urban resilience capacities, including robustness, diversity, redundancy, inclusivity, equity, efficiency, flexibility, resourcefulness, and reflection [21], leading to incomplete findings. Consequently, researchers [(e.g., 10, 11, 13, 14)] have noted that the relationship between smart city practices and urban resilience remains unclear. This study bridges this gap by linking a broad range of urban resilience capacities with smart city dimensions in Amman.

Research on the relationship between smart city practices and urban resilience is lacking [9,13, 19,20,22,23,24]. Sharifi and Yamagata [25] argue that understanding this relationship requires establishing city-level assessment frameworks, as urban indicators can vary significantly between cities. Analyzing the contribution of smart cities to enhancing resilience provides valuable insights for improving sustainable development and offers practical solutions for strengthening cities' capacity to withstand challenges and disasters. This study addresses the following research questions: (1) What criteria are employed to assess the impact of smart city practices on urban resilience? (2) How do smart city practices influence Amman's resilience? (3) What obstacles does Amman encounter in enhancing urban resilience?

This study focuses on Amman City, the capital of Jordan, for several reasons. First, Jordan has made significant progress in the development of smart cities, as evidenced by the inclusion of

Amman in the Smart City Index 2024 [26]. The ICT Development Index 2024 indicates that Jordan's global score in ICT stands at 84.9%, which is considered high [27]. Finally, research on this area in the context of developing countries is lacking [12].

2. Smart City and Urban Resilience

The concept of smart city focuses on linking urbanization process to information technology [24,28]. Prior research has offered various interpretations of smart cities theory. For example, the European Commission [28] considers a smart city as one that utilizes technological innovations to enhance quality of life and sustainable development. Giffinger et al. [29] view a smart city as one that adopts smart actions to rise services efficiency provided to dwellers. In the same context, Bakıcı et al. [30] characterize a smart city as a location that connects the population, information, and different socio-economic sectors through technology to attain sustainable development, optimize quality of life, and foster economic activities. Consequently, these concepts suggest that smart cities comprise three essential components: ICTs, quality of life, and sustainability. Resilience refers to the ability to successfully navigate challenges within social, economic, political, and environmental systems [31,32,33,34,35,36]. Wagner and Breil [37] argue that urban resilience is the ability of society to control crises and shocks. Hamilton [38] indicates that urban resilience is the capacities of governments to recover major functions of life and production over crises. Wang et al. [39] and Leichenko [40] consider urban resilience as the ability to withstand a wide range of stresses and shocks. Consequently, urban resilience is a transformative strategy to enhance a city's capacity to control and adapt to changes over time, which involves improving complex systems [41]. This transformative strategy encompasses ecological, economic, social, infrastructural, institutional, and societal

elements. Therefore, urban resilience can be considered a transformative strategy for shaping urban policies.

Several frameworks have been developed to help understand smart cities and urban resilience. For example, Giffinger and Gudrun [42] introduced a model for smart European cities, while Nam and Pardo [43] developed the fundamental components of a smart city model. Additionally, Chourabi et al. [44] established a framework for smart city initiatives, and Cohen [22] developed the Smart City Wheel (SCW). Furthermore, both Cohen [22] and Giffinger and Gudrun [42] delineated six dimensions of a smart city: smart environment, smart mobility, smart governance, smart economy, smart living, and smart people. These dimensions contribute to enhancing resilience capacities. These capacities include robustness, diversity, redundancy, inclusivity, equity, efficiency, flexibility, resourcefulness, and reflection [25].

Robustness denotes a system's capacity to withstand external stresses and disturbances, focusing on the quality of urban infrastructure for resilience, which involves the construction and management of physical assets to mitigate the adverse effects of hazards [45]. Diversity involves integrating various modes into the system [14]. Effectiveness depends on various instruments and resources, which are critical for handling shocks and ensuring the continues of processes across the urban system [45]. Redundancy enhances the system's ability to withstand failures in individual components, thus preventing a total system failure [46]. Inclusivity involves engaging communities and stakeholders in the decision-making process to strengthen social capital and improve the economic performance of urban resilience [46]. Equity ensures that resilience includes all social groups can access to services during crisis, mitigating negative outcomes [1]. Efficiency ensures that the urban system optimizes resource utilization and waste management [47].

Connectivity indicates that the urban system, composed of multiple subsystems, can achieve the overall efficiency of the urban system. Connectivity utilizes accessible resources to address shocks and emergencies [25,39]. Flexibility denotes the capacity of urban systems to adapt to changing conditions [48], facilitating the introduction of necessary modifications to address challenges. Resourcefulness primarily focuses on the availability of diverse sources and their capability to manage the repercussions of unforeseen disasters [9, 46]. It deals with the ability of residents and organizations to urgently find solutions to meet their needs during crises [48]. Reflection is a mechanism that continuously improves and adjusts criteria in response to crises, rather than relying on static solutions [31,40]. Agility signifies a system's efficiency in mobilizing the necessary resources for recovery, enabling a swift return to normal functioning within a suitable timeframe. This adaptability is critical in preventing failures that could disrupt other functions within the system [1].

Resilience capacities are strongly linked to the dimensions of smart cities, which contribute to the development of sustainable urban environments, as shown in Figure 1. Urban smartness utilizes ICTs to enhance sustainable development and improve the quality of life in the long run. Smart cities are based on social, economic, and environmental pillars. Both smart cities and resilience require realistic indicators of resource utilization to address crises and enhance social well-being [49]. Seong and Jiao [11] argue that smart city resilience aims to stimulate innovative solutions, address unexpected shocks, and foster inclusive, sustainable, and resilient communities. Baron [19] linked a smart city to a resilient city, highlighting that both concepts are inseparable in urban research. Zhou et al. [20] examined the role of smart cities in achieving urban resilience in China. They found that smart cities have significantly improved social resilience

without any adverse effects on infrastructure, economic, or ecological resilience. Quintero and Sharifi [13] observed that smart infrastructure helps cities to meet disasters and innovations contribute to optimizing resilience, including creativity, flexibility, connectivity, agility, and inclusion. Yao and Wang [18] argue that innovation and connectivity are enhanced by smart city practices. These capacities also strengthen information exchange between citizens and governmental institutions (Johnson et al., 2020).

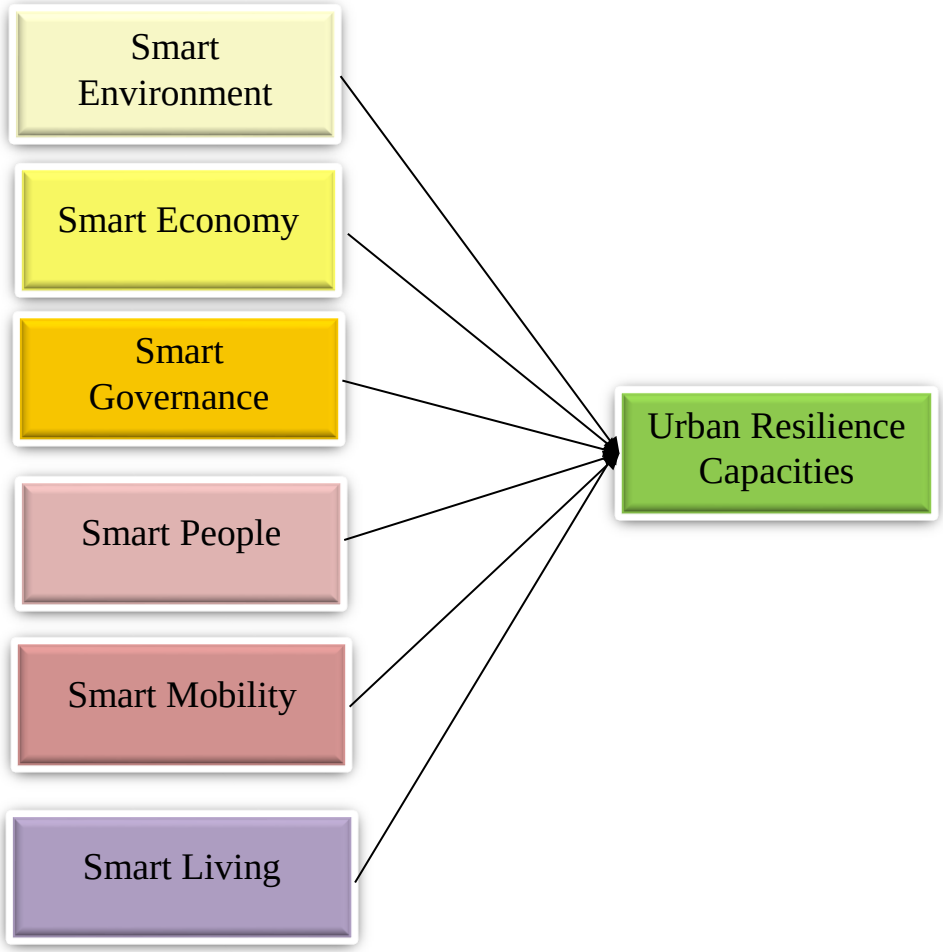

Figure 1. The affiliation between smart city practices and urban resilience

3. Method and Materials

This research aims to evaluate the affiliation between smart city practices and urban resilience in Amman. Amman is the capital of Jordan, with a population size of 4,007,526 inhabitants and an area of 7579.2 km². It is the largest governorate in Jordan in terms of population, services, and business activities. The city is situated in the center of the country, as outlined in Figure 2. Amman is the administrative center of all government offices and parliament.

Figure 2. Location of Amman

Based on the literature [(e.g., 10,11, 13, 14, 17, 19, 20, 23, 25, 41, 46)], we developed an assessment framework that encompasses six dimensions of smart cities and thirteen capacities of urban resilience, totaling sixty-eight indicators. These indicators, which were obtained from previous studies, such as [35, 45, 46, 47, 48], address all dimensions of smart cities

and capacities of urban resilience, as detailed in Appendix A. To evaluate the indicators included in the assessment framework, we developed a Likert scale ranging from 1 (poor) to 5 (excellent). Consequently, we targeted a purposive sample consisting of 160 experts, managers, and academics to assess these indicators. These participants possess comprehensive knowledge and extensive experience in smart cities, urban resilience, and urban environment development. They are involved in developing policy instruments for urban smartness and resilience.

Of the 160 online questionnaires sent to managers, 103 were returned completely, resulting in a response rate of 64%. We assessed the internal consistency of the questionnaire items using Cronbach's alpha, and all values exceeding 0.80, as shown in Table 2. The items included in the questionnaire are presented in Appendix A.

Table 1 Profile of experts

Sectors	Sent Questionnaires	Returned Questionnaires
Public sector	45	36
Private sector	28	19
Academic sector	55	41
United Nations Organizations	12	7
Total	**160**	**103**

Table 2. Results of the reliability test

Variables	Cronbach’s values
Urban Resilience	0.842
Smart Environment	0.873
Smart Economy	0.865
Smart People	0.821
Smart Living	0.880
Smart Mobility	0.817
Smart Governance	0.839

4. Results and Discussion

4.1 Urban resilience capacities and smart city dimensions

There is a consensus among respondents that smart city practices can enhance urban resilience capacities. Figure 2 shows that all urban resilience capacities improved significantly due to smart solutions. The results indicate that equity has the highest capacity supported by smart solutions. In Jordan, all individuals have equitable access to information and services, regardless of race, ideology, education, culture, or nationality. Additionally, capacities such as resourcefulness, efficiency, transparency, and robustness have achieved high progress compared to others. Generally, the results indicate that smart solutions have efficiently supported urban resilience. The findings also indicate that agility and diversity exhibited the least progress, highlighting the necessity for further enhancement.

The analysis shows that Amman has achieved significant progress in smart city dimensions. Figure 2 illustrates that Amman has succeeded in developing effective smart strategies, establishing smart projects, optimizing smart services, and enhancing coordination instruments. Hence, smart city practices in Amman serve as a suitable model for enhancing urban resilience. Figure 2 shows that smart mobility has the lowest value. Although Jordan utilizes Intelligent Transportation Systems (ITS), an effective general platform for implementing a smart mobility system has not yet been established. To enhance smart mobility, it is essential to improve intelligent services such as information of parking, web portals, roadside message panels, and smart applications. Such services enhance accessibility, reduce traffic congestion, and increase transportation efficiency.

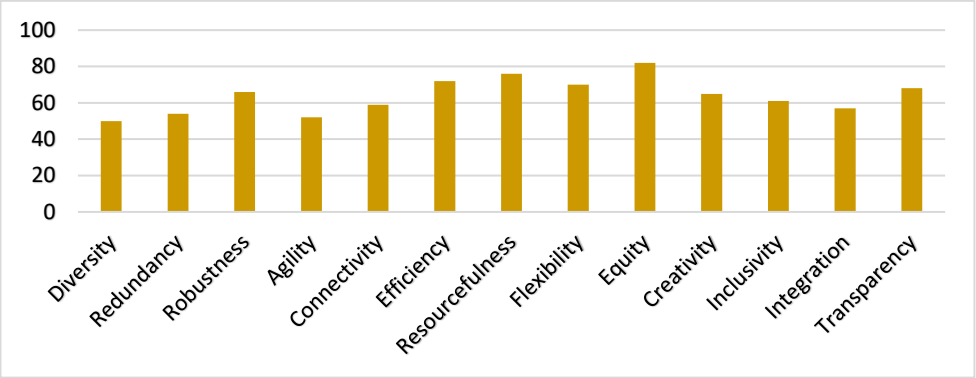

Figure 1. The relationship between a smart city and capacities of urban resilience

Figure 2 indicates that urban governance holds the highest value. Jordan has developed the National Digital Transformation Strategy & Implementation Plan (2021-2025), which aims to facilitate digital transformation across key sectors, including education, health, justice, energy, social security, transportation, and financial services. This initiative is based on the integration of Big Data, Blockchain, the Internet of Things (IoT), and Artificial Intelligence (AI) [50]. The government has implemented a service system that relies on a shared digital platform. Additionally, the strategy focuses on priorities and needs from residents' perspectives to enhance the decision-making process. Therefore, smart governance has contributed highly to improving urban resilience.

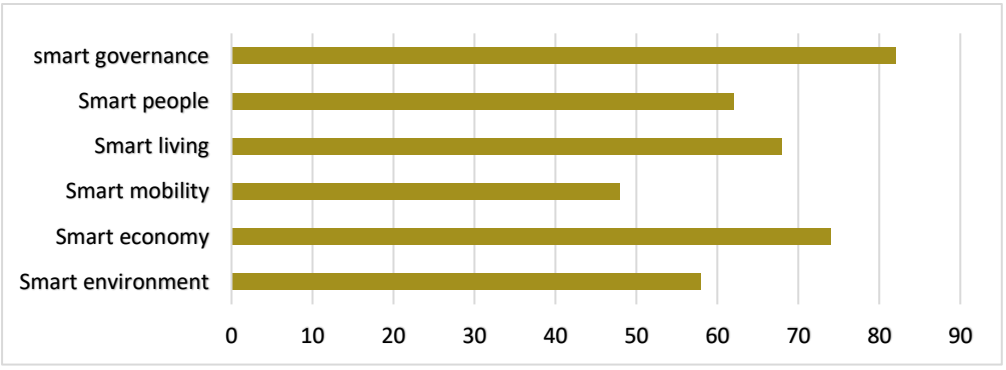

Figure 2 presents the importance

4.2 The impact of smart city practices on urban resilience

4.2.1 Descriptive statistics

Table 3 presents the descriptive statistics for the study variables. The results indicate that governance has the highest average score of 3.865, suggesting that urban institutions have effectively transitioned their services to electronic platforms. The standard deviation values for all variables are below 1, which indicates a high level of precision in the means of these variables. The skewness values are within the acceptable range of -1 to 1, and the kurtosis values fall within the range of -3 to 3, indicating the variables are normally distributed.

Table 3. Descriptive Statists

Variables	M	SD	Min	Max	Skewness	Kurtosis
Urban Resilience	3.411	0.425	1	5	-0.425	0.988
Smart Environment	3.125	0.822	1	5	-0.714	-1.047
Smart Economy	3.906	0.685	1	5	0.522	1.314
Smart People	3.712	0.754	1	5	0.381	0.885
Smart Living	3.368	0.920	1	5	-0.686	1.088
Smart Mobility	3.102	0.550	1	5	-0.847	-1.468
Smart Governance	3.865	0.843	1	5	0.572	-0.853

4.3.2 The effect of smart city practices on urban resilience

The regression findings presented in Table 4 indicate that the R-value reflects an overall correlation of 70.18% among the study variables. The R^2 value suggests that the independent variables explain 51.6% of the variability in urban resilience, with an adjusted R^2 of 0.512, which is close to the R^2 value. The F statistic is significant at the 0.01 level. Table 4 confirms the absence of multicollinearity issues, as the tolerance and variance inflation factor (VIF) values are below the commonly accepted threshold of 10, and all tolerance values exceed the minimum

threshold of 0.2. Therefore, there is no evidence of multicollinearity. The Durbin-Watson statistic is 1.544, which falls within the acceptable range of values between 1 and 3. Therefore, the regression model is deemed fit. The histogram in figure 3 shows that the distribution is almost normal in the dependent variable.

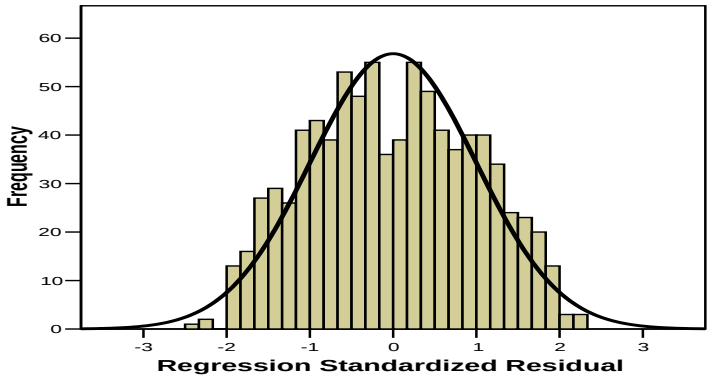

Figure 3. The histogram of normal distribution of dependent variable

The straight line in this plot shows a normal distribution and the points represent the observed residuals. For the normal probability plot shown in figure 4, it can be seen that, in general, the observed residuals follow the line. Although there are some deviations away from that line, these are not far from it and so the overall trend for these residuals is that they follow the line representing a normal distribution.

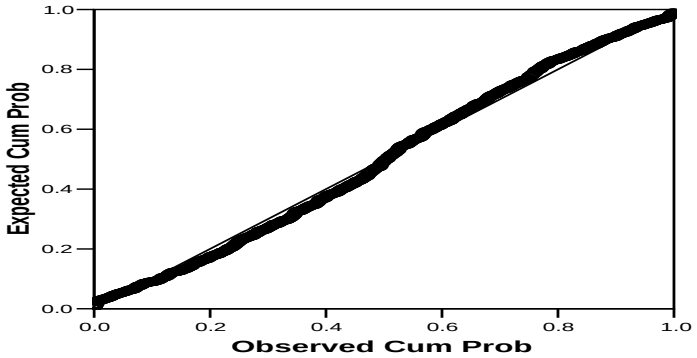

Figure 4. Histogram and normal plots of dependent varaible

Empirical findings indicate that the smart environment positively affects urban resilience, with a beta coefficient of 0.186 at a significant level of 0.05. Jordan has increasingly utilized ICTs for sustainability and resilience, thereby improving the efficiency of environmental management practices. Amman has established a network of multiple air quality monitoring stations and implemented a Smart Electric Meter system, which optimizes data collection and analysis, strengthening energy conservation efforts. These actions have successfully solved problems with wastewater treatment, recycling, and reusing treated greywater. In order to improve the urban environment, Amman has recently started a number of smart initiatives, such as Abdali Boulevard, the Green Amman program, and the Amman Bus Rapid Transit system.

Table 4. Multiple Regression Analysis

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	t-value	Sig.	Tolerance	VIF
	B	SD. Error	Beta				
Constant	0.484	0.359	-	1.348	0.139	-	-
Smart Environment	0.185	0.060	0.186	3.083	0.041	0.894	1.118
Smart Economy	0.254	0.056	0.328	4.535	0.000	0.805	1.242
Smart People	0.200	0.058	0.288	3.448	0.024	0.739	1.352
Smart Living	0.190	0.061	0.242	3.114	0.032	0.446	2.241
Smart Mobility	0.071	0.088	0.115	0.806	0.426	0.701	1.426
Smart Governance	0.286	0.054	0.411	5.296	0.000	0.754	1.325
R = 0.0.718							
R^2 = 0.516							
Adjusted R^2 = 0.512							
F = 13.211 Sig. 0.000							
Durbn-Watson = 1.544							

Level of Significance is 0.05 or less

Table 4 reveals that smart economy positively affects Amman's resilience, with a beta coefficient of 0.328 at a significance level of 0.01. In order to maintain economic resilience, Jordan has recently attempted to diversify its economy by combining ICTs, knowledge, innovation, and strategic alliances. Several smart initiatives that make use of strategic assets and local resources to improve economic resilience have been established as a result of this integration. This vision has increased investment prospects and greatly enhanced labor market flexibility. The government has implemented a number of programs, such as development zones and industrial cities, to increase sustainability and resilience. By creating possibilities for the workforce, these programs have developed a resilient workforce that can move between different industries or vocations in response to various crises.

Table 4 illustrates that smart people positively affect Amman's resilience, as beta value of 0.288 is significant at the level of 0.05. This finding suggests that locals have a high level of resilience knowledge, which empowers them to handle a range of emergencies and chocks. According to the International Telecommunication Union [27], the internet usage rate among individuals stands at 90.5%, with households also achieving a 92.2% rate of internet access, and there are 67.6% mobile broadband subscriptions per 100 inhabitants. The presence of knowledge hubs, online services, mobile applications, and other technological resources has enhanced the community's capacity to respond effectively to crises. Collaborative efforts among universities, industries, and government entities have further elevated awareness levels. For example, Al Hussein Technical University (ATU), German Jordanian University, and Princess Sumaya University for Technology in Amman are innovative initiatives to strengthen the resilience of Jordan. These universities include science and technology parks, facilitating the

exchange of information and knowledge. They provide advanced research and development to enhance economic resilience. These universities exemplify a knowledge-based economy through technical learning and training, whereby knowledge is transformed into economic value through innovation rather than reliance on traditional resources. They have improved the learning process and facilitated the dissemination of knowledge within the community, thereby enhancing the country's resilience. A pertinent example of this is Amman's effective management of the COVID-19 crisis, during which the city leveraged its substantial technical capabilities to navigate the pandemic with adaptability to exceptional circumstances, thereby minimizing disruptions to work and supply chains.

The results illustrate that smart living has a positive impact on the resilience of Amman, as demonstrated by a statistically significant beta coefficient of 0.242 at the 0.05 significance level. The concepts of urban smartness and resilience have been employed interchangeably across various frameworks to align with the national objectives of urban development. This alignment involves the integration of sustainable development goals within smart city initiatives to address challenges related to climate change and disasters. For example, the construction of smart buildings has enhanced Amman's resilience by reducing reliance on traditional energy sources and promoting the utilization of renewable energy sources. The city's digital and telecommunications infrastructure, including Wi-Fi, cellular networks, and IoT connectivity, operates as a microgrid that efficiently utilizes data. A diverse system of advanced sensors enhances information and improves residents' responsiveness during crises. Additionally, Amman has embraced resilience principles that enhance public services and technological infrastructure, thereby improving safety and security for residents.

The findings show that smart mobility has a negative impact on Amman's resilience, with a beta value of 0.115, which is exceeded a significance level of 0.05 level. This outcome highlights the transportation system's poor ability to effectively respond to crises and may be attributed to challenges in getting high-quality, real-time data about parking availability and traffic movements. Our empirical results align with Aldegheishem [12], who found that smart mobility suvers from sever challenges in Saudi Arabia compared with other smart city dimensions. Additionally, the urban planning system has failed to establish sustainable transportation. Therefore, the government should establish smart projects to improve smart mobility in the city.

The empirical findings show that smart governance has significantly enhanced the resilience of Amman, as reflected by a beta coefficient of 0.411, which is statistically significant at the 0.01 level. As a powerful political instrument, smart governance impacts all dimensions of smart cities and oversees the management and operation of resilience capacities. Amman has enhanced its governance system by implementing several practices, including the Internet of Things (IoT), big data, and social media platforms. For instance, allocating platforms for people to provide suggestions for governmental bodies and institutions are open-source intelligent tools that promote local community engagement. People with different educational backgrounds can share knowledge and make ideas on these platforms. In order to connect the public with the government and promote community involvement, they incorporate effective communication channels. Additionally, safety and security have been greatly enhanced by the installation of cameras across public areas, buildings, and streets. To sum up, Amman has successfully matched its goals for smart governance with

programs for urban resilience. The results show that Amman's urban resilience is significantly increased by implementing smart city initiatives. Such findings are consistent with previous studies (e.g., [51,52,53,54,55,56,57,58,59,60,61]). ICT has been successfully incorporated into urban resilience through smart city initiatives, particularly the most recent projects that cover all aspects of smart cities. Finally, ICT has helped reduce several challenges in Jordan, including bureaucracy, corruption, and regulatory gaps.

5. Conclusion and implications

This research has established an assessment framework to examine the link between smart city practices and urban resilience in Amman. The framework consists of 68 indicators. These indicators were evaluated by experts from various sectors. The results show that, with the exception of smart mobility, every dimension of smart cities has greatly improved urban resilience in Amman. According to these findings, smart city strategies have offered innovative ways to encounter unanticipated risks and shocks while fostering a sustainable environment. The results demonstrate how well Amman's smart city initiatives are working to raise living standards and promote sustainable growth. An important prerequisite for enhancing urban resilience is the efficient operation of urban institutions, as shown by Amman's smart city approach. Smart network technologies are needed to improve urban resilience and raise the performance of urban institutions.

Urban resilience is unaffected by smart mobility. Among many issues facing the transportation is the shortage of sufficient real-time data collection on parking availability and traffic flow. Enhancing access to real-time data could be achieved by fostering information exchange among local authorities and

utilizing advanced technologies, such as artificial intelligence and big data analytics. Therefore, the government should develop a comprehensive strategy to strengthen smart mobility. The successful implementation of this strategy will require the engagement of various stakeholders, including the public and private sectors, academic institutions, local communities, experts, and local media.

The assessment framework developed in this study offers valuable insights for local authorities and researchers aiming to create frameworks for evaluating the connection between smart city initiatives and urban resilience in other cities. However, a significant limitation of this study is that it relies on a single case study, which limits its applicability at the national level. Consequently, future research should concentrate on developing an assessment framework that can be applied at the national level. This study is a cross-sectional survey; therefore, researchers should consider conducting longitudinal studies to better assess urban resilience. Additionally, the study's sample has been limited to experts, managers, and academics, who possess extensive knowledge in this field. Future research should broaden the sample to include citizens, which would offer a more comprehensive perspective on the relationship between smart city practices and urban resilience.

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Appendix A

No.	Environment
1	Monitoring air quality using ICT
2	Monitoring water quality using ICT
3	Effectiveness of smart metering systems (energy/water)
4	Existing real time data for food consumption
5	Existing real time data for energy demand
6	Existing real time data for water demand
7	Use of renewable energy
8	Smart grids penetration
9	Enabling smart energy
10	Utilizing smart practices in waste collection, disposal, and treatment
11	Resilient urban development (mixed land use, dwelling closeness to work, compact)
12	Effectiveness of ICT in service delivery to people with disabilities and special needs
13	Ability of all community groups to access smart devices
14	Using ICT to resolve technical problems in infrastructure services
15	Rapid communication between citizens and public authorities for emerging problems with infrastructure
	Economy
16	Availability of sufficient funds for emergencies
17	E-commerce transactions share
18	E-business transactions share
19	Knowledge economy contribution to GDP
20	Number of new businesses
21	Public expenditure on smart city projects
22	Effectiveness of online promotion for tourism
23	Home-based work
24	Flexibility of work hours
25	The level of cost reduction for urban authorities using ICT

	People
26	Rate of internet penetration
27	Rate of social networking penetration
28	E-learning usage
29	Level of ICT knowledge and technical capacity
30	Quality of training programs to enhance digital skills
	Living
31	Use of digital health portals
32	Use of electronic health records
33	Role of smart solutions in security and safety
34	Systems of crime protection
35	Readiness of telemedicine infrastructure for shocks and disaster
36	Use of ICT for operations, diagnostics, and medications
37	Efficiency of ICT solutions to enhance wellbeing
	Mobility
38	Efficiency of infrastructure to provide real-time traffic flow information
39	Effectiveness of wireless infrastructure
40	Readiness of Web 3.0 to deal with disasters
41	Ratio of green transportation
42	Existence of real-time information about parking
43	Maintenance of ICT infrastructure
44	Demand information for transportation in the long run
	Governance
45	Presence of smart plans for city resilience
46	Presence of smart city vision and comprehensive roadmap
47	Effectiveness of frameworks and monitoring approaches for performance of smart cities
48	Level of coordination between public authorities and information exchange
49	Integration of smart solutions into risk strategies
50	Efficiency of employees when dealing with ICT

51	Effectiveness of training programs for employees in the context of ICT
52	Presence of warning systems for shocks
53	Quality of online systems which receive comments from the public
54	Efficiency of employees when managing disaster
55	Overall capacity of current smart governance when tackling disasters and shocks
	Urban System Resilience
56	The robustness of urban system to avoid external stresses and disturbances, ensuring high-quality infrastructure, construction, and management of physical assets
57	The diversification of instruments and resources in urban system to control disturbances and ensure functionality
58	The ability of urban systems to cope with the failure of one component, ensuring that the entire system avoids a complete breakdown
59	Engaging communities and individual stakeholders in the decision-making process
60	The ability of people to access services and recover from disruptions
61	Resource-efficient use, including waste management and energy, within urban systems
62	The ability of urban systems to connect with all other sub-systems and organize their operations to enable the efficiency of the overall urban system
63	The ability of urban systems to utilize available resources to deal with shocks and emergencies
64	The ability of urban systems to coexist with changing conditions
65	The ability of residents and organizations to urgently find solutions to meet their needs during a crisis
66	The availability of instruments in urban systems to continuously enhance and alter criteria according to new challenges, instead of dealing with static solutions
67	The ability of urban systems to efficiently mobilize the required resources for recovery, enabling a prompt return to normal functioning within a suitable imeframe
68	Urban systems' ability to prevent cascading failures