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Smart City Dimensions and Associated Risks: Review of literature

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ABSTRACT

Countries have been working on implementing smart city concepts in different regions. The need for the use of information and communication technology in various forms is needed in such cities. There are different dimensions that are to be considered for smart city planning and implementation. This complexity of the dimension, the use of technology, and their integration bring the risk perspectives into the implementation of the smart city concept. If such risks are not adequately understood and addressed, they can create issues in terms of privacy and security and, therefore, the functioning of smart cities. In this review, the identification of dimensions, smart city assessment tools, the available technologies, and the technical and non-technical risk parameters related to smart cities implementation are discussed. The current methods of risk assessment and the possible enhancements are highlighted. The findings of the literature review illustrate that not all smart cities adapt all of the smart city dimensions. The dominant technology used in smart cities' applications is found to be the Internet of Things, Artificial Intelligence, and blockchain. The paper also provides some research directions for the design, implementation, and operation of smart cities.

1. Introduction

The smart city concept was first introduced in 1990 in order to incorporate advanced information and communication technology (ICT) based hardware and software in urban planning (Bibri & Krogstie, 2017). Smart city utilizes ICT to enhance 'citizens' quality of life, foster economy, facilitate a process to resolve transport and traffic problems through proper management, encourage a clean and sustainable environment, and provide accessible interaction with the relevant authority of the government (Ismagilova, Hughes, Dwivedi & Raman, 2019). The increased urban expansion and innovations in urban planning and ICT have encouraged planners to focus on promoting the smart city's concept, which considers the well-being of the urban population by focusing on a combination of human, environmental, social, cultural, energy, information access and usage, and other technological advances. Studies have suggested smart mobility as a dimension in the smart city (Apostol, Bălăceanu & Constantinescu, 2015).

Urban planning based on the smart city concept is expected to overcome urban challenges as congested transportation, high carbon energy network, infrastructure maintenance and repair, and urban security and policy (Golubchikov & Thornbush, 2020) and use advanced technology and systems. For instance, cities like Dubai, Hong Kong, London, New York, Moscow, and Ottawa have adopted AI and robotics to develop smart applications (Golubchikov & Thornbush, 2020). It should be noted that there are associated risks with these technologies, which can create threats to the operation of a smart city (Golubchikov & Thornbush, 2020).

Due to the complexity of systems needed for smart city development, the functionality of smart city systems becomes vulnerable. Such vulnerability can be due to operational risks, strategy risks, and external risks (Mikes, 2012). Techatassanasoontorn and Suo (2010)mention socio-political risks, approval risks, financial risks, technical risks, partnership risks, and resource management risks for smart cities. Risks are also associated with the security and privacy within the smart city systems (Čolić, Manić, Niković & Brankov, 2020),(Mohamed, Al-Jaroodi, Jawhar & Kesserwan, 2020). Risks consideration in the smart city may focus on the individual system as it might be easier to identify them for the implementation of the risk management strategy to mitigate the impact. For example, energy systems risks are highlighted by (O'Dwyer, Pan, Acha, & Shah, 2019). Similarly, Sharma et al. (2020) discuss the associated challenges and risks in the smart city waste management system. However, studies should consider totality in terms of risk assessments in smart city planning and operation. Assessment of such risks in totality is essential to reduce challenges of smart city projects from all

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different aspects; technology, security and privacy, political, environmental, managerial, and user trust and adoption. Such a risk assessment can highlight the risk potential in different aspects of the design and operation of a smart city (Ismagilova, Hughes, Rana & Dwivedi, 2020).

Although researchers discuss smart cities' themes, services, technologies, innovations in relation to 'citizens' engagement, only a limited number of studies focus on governance policies, performance indicators, and standards. Convenience research is desired in these aspects to provide comprehensive information for government and policymakers about smart cities at a holistic level (Gupta, Chauhan & Jaiswal, 2019), (Lytras, Visvizi, Chopdar, Sarirete & Alhalabi, 2020).

Governance of a smart city is another essential aspect that requires effective collaboration between government, stakeholders, citizens, and socio-technical systems. Governance requires a complex framework, policies, and procedures (Ben Yahia, Eljaoued, Bellamine Ben Saoud & Colomo-Palacios, 2019).

Smart cities are depending on smart people who are looking for social sustainable living. Sustainability in this context includes reduction of non-renewable resource use, conservation of environment, diverse and robust economy, independent communities, and economic vitality and diversity, autonomy in communities, citizen well-being, and satisfaction of basic human needs. The utilization of ICT is expected to facilitate 'citizens' participation, enhance the growth of human, social, and environmental assets of smart cities, and create social-oriented smart cities (Bouzguenda, Alalouch & Fava, 2019). Policies extracted from the user's perspectives and their satisfaction, community perspectives, and the focus on neighborhood design are essential to support sustainability in smart cities (Macke, Rubim Sarate & de Atayde Moschen, 2019).

This paper focuses on a review of the literature to investigate smart city risk assessment tools and techniques and the latest technological advancement and innovations in relation to risk assessment and management. To achieve this goal, a comprehensive understanding of smart city's dimensions and used technologies is crucial. The paper concludes with research opportunities in risk assessment tools for a smart city implementation project.

Further discussion in this paper is organized as follows. The methodology adopted for the review is given in Section 2, followed by literature analysis and results in Section 3. The research on smart city dimensions, associated technical and non-technical risks in smart cities, risk assessment tools and techniques are also discussed in Section 3. The discussion of results is presented in Section 4. Finally, conclusions and further research are provided in Section 5.

2. Methodology

This study uses a content analysis method to review the literature related to opportunities and risks related to smart cities. Content analysis method is a quantitative method, centralized on analyzing and categorizing related text of the research topic. The frequency of occurrence of a topic can also be studied through such an analysis (Kohlbacher, 2006). The method is used in reviews given in, Al-Sobai, Pokharel and Abdella (2020), Bouzguenda et al. (2019)), Islam, Nepal, Skitmore and Attarzadeh (2017), Vidiasova and Cronemberger (2020), and Pokharel and Mutha (2009). To develop the knowledge on the topic through content analysis, the research focuses on the texts that combine smart city with its dimensions, technical risks, non-technical risks, risk assessment tools, quantitative risk analysis and qualitative risks analysis, risk related parameters, and smart applications. Extraction and assimilation of the content based on these words helps to address the research questions outlined in Section 2.1.

The research methodology adopted in this paper is given in Fig. 1. The methodology has three main stages: identification, selection of literature, and literature grouping. In the identification stage, smart city dimensions are investigated, and smart technologies associated with each dimension are inspected. Then risk categories are identified in terms of technical or non-technical risks. The risk assessment tools and techniques are surveyed. In the second stage, journal papers from a different database are obtained by using keywords, consideration rules, and selection criteria. Screening of papers is done based on the relevance of the content of the paper. In the third stage, qualitative analysis of the selected literature is done, and any new categories and subcategories obtained from the literature are also included.

This review reflects published literature between 2010 and 2021, as most research studies concerning smart cities and the associated risks are published within these years (Shayan, Kim, Ma & Nguyen, 2020). Duplicated literature are eliminated before starting the literature analysis.

2.1. Identification

In order to identify the targeted studies, the research questions are constructed. The four research questions considered in this paper are given below.

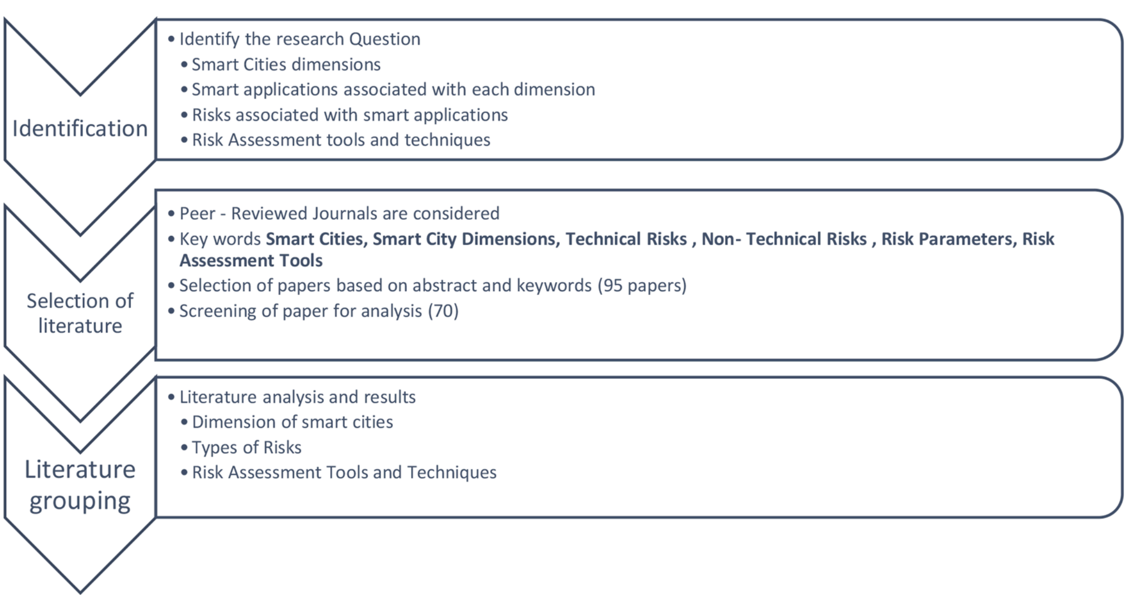

Fig. 1. Framework for the Literature review process.

RQ1: What are the dimensions of smart city considered in the literature?

RQ2: What are the applications associated with each smart city dimension?

RQ3: What are the risks correlated with smart applications, and what are the dominant types of risks?

RQ4: What are the available risk assessment tools and techniques that are explicitly used for risk assessment and management in smart cities?

2.2. Selection of literature

Literature search focused on electronic databases of journals, mainly ScienceDirect, Scopus, IEEEXplore, Taylor & Francis, and Wiley. Following a collection of words and Boolean connectors to access the most accurate information: Smart Cities, Smart City Dimensions, Technical Risks, Non- Technical Risks, Risk Parameters, Risk Assessment Tools, with "AND," “OR” are used. Besides, the published year to be between 2010 and 2021 is specified. This search resulted in the selection of 247 papers, including journals and conference papers.

Conditions are applied to determine the included\excluded papers based on the criteria of including journal papers and avoiding conference papers and research language in English. Peer-reviewed journals are considered to ensure the reliability and quality of the publication. The process resulted in the collection of 95 articles.

Manual assessment of the collected journal articles was executed to exclude irrelevant papers. Some of the papers were disregarded because they were outside the scope of this study, for instance, smart city sensors design, IoT technical specifications, design aspects of smart energy systems, and urban planning for smart cities. This assessment led to a final list of **86** journal articles used to answer the specified research questions.

2.3. Literature grouping

From the obtained literature, more than 80% of the papers are found to be published in 2019, 2020, and later, which shows the emergence and importance of recent interest in research related to a smart city.

From the collection, 38% of studies are related to smart city definition and dimensions, 35% related to technical risks in smart cities, and 8% focusing on non-technical risks; among the papers, 16% provide risk assessment tools and techniques for specific technical risks associated with smart cities’ applications and other complex technology projects. Five percent of the literature considers smart city assessment in terms of services feasibility and their role in increasing citizens’ quality of life. Fig. 2 illustrates the number of papers based on the literature characteristics, which will be demonstrated in the following sections.

2.4. Literature summary

The following table provides the distribution of papers in smart city dimensions, risks, risk assessment tools, and the smart city dimension framework. The discussion on these contents is presented next.

3. Literature analysis and results

Fig. 3 shows the flow of literature analysis used in this paper. Smart city dimensions obtained from the literature are shown in the figure. Each dimension is associated with technical and non-technical risks. Although early detection and assessment of risks will reduce costs of implementations, increase users adaption, ensure better services and increase citizens’ quality of life (Sandeep, Honagond, Pujari, Kim & Salkuti, 2020), only limited literature was found to focus on risk aspects.

3.1. Smart cities dimensions

Smart cities are generally planned based on four pillars: institutional infrastructure, physical infrastructure, social infrastructure, and economic infrastructure. Smart cities’ dimensions are constructed to support these pillars (Silva, Khan & Han, 2018). This section provides the answer for RQ1 and RQ2. The dimensions of smart city considered in the literature, in terms of definitions, smart applications, and the dominant used technology, are discussed in this section. Table 1 illustrates the number of reviewed papers for each smart city dimension.

3.1.1. Smart economy

Apostol et al. (2015)) studied smart economy prospectives and mention that smart economies comprise guidelines and policies that inspire innovation and creativity in collaboration with scientific research, advanced technology, and the sustainability concept’s attention to the environment. Arroub, Zahi, Sabir and Sadik (2016) present smart economy as innovation, competitiveness, use of information and communication technologies in the overall aspect of the economy, and the socially responsible use of resources. Based on their study related to validity of conventional economical theories and practice in smart cities . Kumar & Dahiya (2017) acknowledge that a smart economy also means a knowledge economy based on state-of-the-art research in all disciplines such as science, industry, business, cultural heritage, architecture, planning, and development.

The smart economy in smart cities takes many forms and

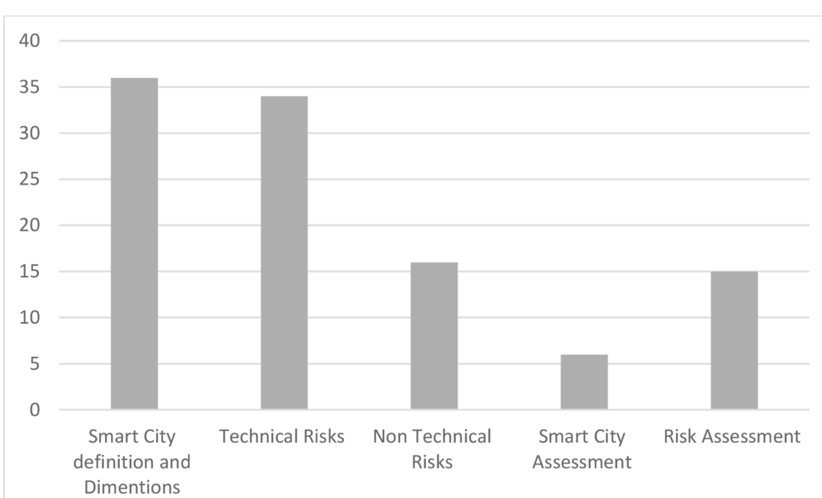

Fig. 2. Number of journal papers per objective.

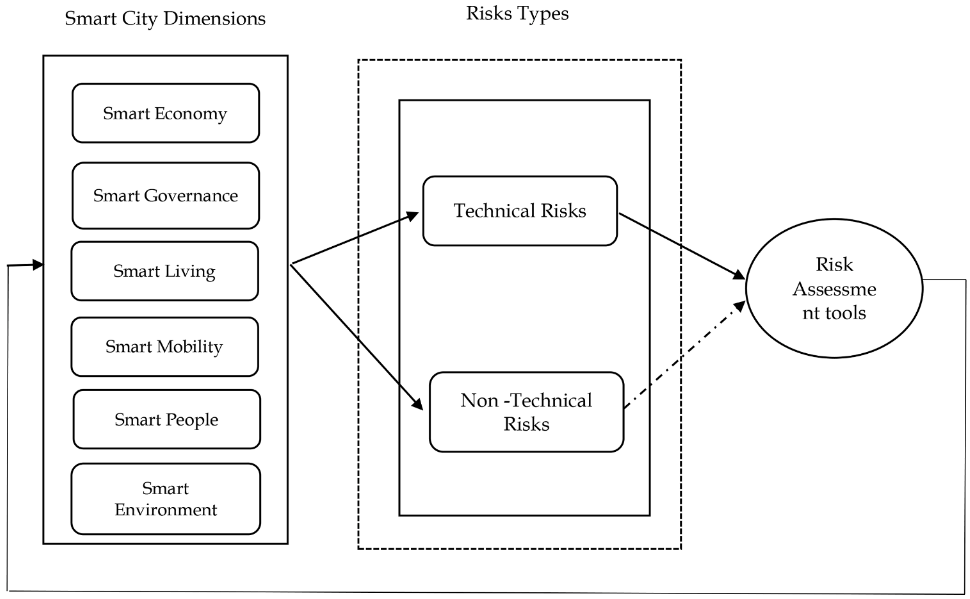

Fig. 3. Flow of Literature Analysis.

applications; each has unique characteristics, challenges, and solutions. Table 2 below illustrates some of the reviewed applications related to the smart economy dimension. Reviewed studies highlight forms of the smart economy, applications, and challenges that can lead to non-technical risks associated with each discussed application. The authors' recommendations are illustrated to overcome the mentioned challenges.

3.1.2. *Smart governance*

Silva et al. (2018) have studied smart city dimentions and challenges situation. The authors show that smart cities' governance is allied with the contribution to decision-making, public services, social services, transparent governance, and policies and strategies. The authors mention governance as coordination between citizens and administrative institutions and a successful governance can help to achieve maximum benefits of smart cities in terms of reliability, efficiency, and effectiveness of citizens' services by integrating public, private, and civil officialdoms. They illustrate that technical governance is crucial in smart governance since it assures addressing all city services and features through high technological solutions (Silva et al., 2018. Based on his study on smart city dimensions categorizations and ways to increase smart cities ability to be innovative . (Nilssen, 2019) emphasizes governance as the primary building block in the collective efforts to develop effective interactions between all actors of smart cities. The author recommend interactive governance to promote open innovation. Such an interaction might be facilitated through e-governance (Ismagilova et al. (2019), which can help in building transparency in decision-making. Such e-governance can be enhanced through the use of 5 G technologies, IoT, and artificial intelligence (AI). Further, Ismagilova et al. (2019) also mention the use of cloud-based information services can help in decision making as it can support participation, engagement, and information sharing for collaborative governance. Table 3 highlights some of the related research in the area of governance.

3.1.3. *Smart living*

OECD Better-Life Initiative framework (Measuring Well-Being & Progress, n.d.) considers the development and preservation of natural, economic, human capitals are elements of smart living. Ismagilova et al. (2019) mention smart living in terms of smart buildings, education, and healthcare, whereas Silva et al. (2018) mention social awareness as another crucial element for smart living. Healthcare can come through real-time monitoring of the needs of the special care, and emergency support enabled through the ICT, in addition to home re-habitation applications that were raised during the COVID-19 pandemic to assist medical professionals during this time (((Atitallah, Driss, Boulila & Ghézala, 2020), Ismagilova et al., 2019), (Nižetić, Šolić, López-de-Ipiña González-de-Artaza & Patrono, 2020)). It is also mentioned that smart living is an outcome of the smart economy by (Apostol et al., 2015) based on their literature review, Romero, Guédria, Panetto and Barafort (2020) describe the usage of ICT also helps in smart living through networked and internet-enabled automated living space conditioning, lighting, and connected security systems. The authors mention that applications related to smart assistance are used widely in smart homes, these applications gather personal and private data about their users, yet privacy and security risks are not tackled with transparency. From their study on the transparency of smart city products (Elahi, Wang, Peng & Chen, 2019) mention **that** setting standards and specifications for smart applications is crucial to detect and manage the risk associated with these applications. Additionally, Nitoslawski, Galle, van den Bosc and Steenberg (2019) mention that smart living applications are supported through empowering technologies such as cloud storage and computing, AI, machine learning, data mining, and wireless sensor networks. Table 4 illustrates some recommendations for smart living applications challenges.

3.1.4. *Smart mobility*

Appio, Lima and Paroutis (2019) focus on smart mobility concentration on transportation systems and infrastructure. The authors mention that the common issues in cities are traffic problems such as congestions, long queues, and delays. They recommend that the smart system should focus on the usage of private vehicles and provide coordinated choices for people to ease in their commuting. IoT is used to collect real-time data on roads and routing analysis to prospective travelers (Silva et al., 2018). Ismagilova et al. (2019) mention that connectivity of information in the vehicles through IoT, the Internet of Vehicles (IoV), can support traffic safety and efficiency in order to achieve smart mobility. The widespread use of IoT in rural and urban areas can provide a better integrated transportation system for smart mobility (Porru, Misso, Pani & Repetto, 2020). **For** enabling smart mobility Paiva, Ahad, Tripathi, Feroz and Casalino (2021) discuss of smart mobility from multiple aspects such as available developments

Table 1
Literature Summary.

No	Authors	Smart City Dimensions						Risks type		Risk assessment tools	SC Assessments
		Eco	Gov	Living	People	Mobility	Env	Tech	Non-Tech		
1	Allam & Dhunny, 2019; Appio et al., 2019; Bibri & Krogstie, 2017; Gupta et al., 2019; Ismagilova et al., 2019; Lytras et al., 2020; Meadowcroft et al., 2018; Romero et al., 2020; Sandeep et al., 2020; Silva et al., 2018; Singh et al., 2020; Zheng et al., 2020	√	√	√	√	√	√				
2	Alawad et al., 2020; Dimitriadis et al., 2020; Domingos et al., 2008; Edjossan-Sossou et al., 2020; Franchina & Socal, 2020; Islam et al., 2017; Jamshidi et al., 2015; Kandasamy et al., 2020; Namazian et al., 2019; Radanliev et al., 2019; Sadik, Ahmed, Sikos & Najmul Islam, 2020; Subriadi & Najwa, 2020; Techatassanasoontorn & Suo, 2010; Ullah et al., 2021; Yorgos et al., 2019									√	
3	Deveci et al., 2020; Fernandez-Anez et al., 2018; Patrão et al., 2020; Sharifi, 2019; Sharifi, 2020; Westraadt & Calitz, 2020										√
4	Ahad et al., 2020; Atitallah et al., 2020; Habibzadeh et al., 2019; Hamilton, 2020; Löfgren & Webster, 2020; Mikes, 2012; Nižetić et al., 2020; Perera et al., 2014; Radu, 2020; Singh & Helfert, 2019; Sovacool & Furszyfer, 2020; Shayan et al., 2020; Xie et al., 2019; Yigitcanlar et al., 2020; Sun et al., 2016; Zakaria et al., 2019								√		
5	Arroub et al., 2016	√	√	√	√	√	√	√			
6	D'Amico et al., 2020	√	√	√	√	√	√	√			
7	Akande, Cabral & Casteleyn, 2020; Apostol et al., 2015; Carter, 2013.	√									
8	Radonjic-Simic & Pfisterer, 2019	√							√		
9	Bouzguenda et al., 2019		√		√						
10	Ben Yahia et al., 2019; Coelho et al., 2021; Čolić et al., 2020		√								
11	O'Dwyer, Pan, Acha & Shah, 2019			√			√				
12	El-haddadeh et al., 2019;Macke et al., 2019				√						
13	Paiva et al., 2021					√		√	√		
14	Helfert et al., 2015; Porru et al., 2020; Staffans & Horelli, 2014					√					
15	Sharma et al., 2020						√				
16	Ande et al., 2020; Baig et al., 2017; Belanche-gracia et al., 2015; Botello et al., 2020; Caviglione & Coccoli, 2020; Elahi et al., 2019; Golubchikov & Thornbush, 2020; Ismagilova et al., 2020; Lee, 2020; Mehmood et al., 2017; Mohamed et al., 2020; Neshenko et al., 2020; Nitoslawski et al., 2019; Priyanka & Thangavel, 2020; Sengan et al., 2020; Ullah et al., 2020; Vorakulpipat, Ko, Li & Meddahi, 2021							√			
17	Vidiasova & Cronemberger, 2020								√		
18	Kummitha & Crutzen, 2019.	√	√								
	Total Number of Papaers	18	18	15	17	18	16	34	16	15	6

and solutions, enabling technologies such as AI, IoT, big data, and blockchain. The authors also discuss the challenges related to smart mobility. Table 5 provides some of the challenges and issues related to smart mobility.

3.1.5. *Smart people*

The social infrastructure of a smart city is mainly related to human capital and social capital. Human capital is the abilities and proficiencies of a person or a group, while social capital is the number and quality of relations connecting social organizations. The need for better human and social capital for innovation and productivity and smart living is critical for smart cities. Therefore, the role of higher education institutions such as universities is important in developing human capital (Ismagilova et al., 2019). Higher institutes act as knowledge mediators, custodians, and providers of activities to support the people to become smart (Ismagilova et al., 2019). AI and big data are two main technologies used to develop smart applications to enhance knowledge sharing, learning, and teaching (Radu, 2020). However, there might be challenges in terms of the acceptance of security and privacy of information and services provided to the people (Belanche-gracia, Casaló-ariño & Pérez-rueda, 2015). The assurance of quality becomes an essential aspect of higher institutes. Engaging people with the government system through the use of IoT is also mentioned by El-haddadeh, Weerakkody, Osmani and Thakker (2019). For instance, El-haddadeh et al. (2019) show that an e-government website will allow citizens to interact with public services as stakeholders and improvers proactively. Table 6 provides an example of recommendations for some issues related to smart people applications.

3.1.6. *Smart environment*

The smart environment includes improvements of waste discarding, pollution control, energy management, smart grids, and house and facility management, quality of air and water, increases in green spaces, and monitoring emissions (Appio et al., 2019; Ismagilova et al., 2019). Staffans and Horelli (2014) examine the use of technology to maintain the natural resources as the preservation of natural resources requires sustainable methods to manage resources, protect the environment, and to reduce pollution (ex. smart energy grids, to create and consume green energy, and green buildings).

Perera, Zaslavsky, Christen and Georgakopoulos (2014) introduce the Internet of Data and IoT as technologies used to develop applications related to the smart environment. These technologies use different types

Table 2
Smart economy applications.

Forms of application	Issues\Challenges	Examples of Recommendations
Online Platform Economy (Amazon, Alibaba, Airbnb and Uber)	• Information processing and gathering are centralized and controlled by the platforms, which will cause a monopoly in the marketplace. • Platforms work well for individual services and products, yet complex products cannot be purchased through such platforms.	Distributed Market Spaces model. The model is designed to support strategic and operational levels and support complex products exchange, applied in smart city information technology infrastructure . since smart city is characterized by service ecosystem (Radonjic-Simic & Pfisterer, 2019).
Sharing economy in terms of giving and sharing access to goods and services in a coordinated manner using online services (such as car sharing, bike sharing, room sharing, and sharing services)	• Attitude risk is the major challenge facing the sharing economy, and norms and behavior control on sharing.	The government should encourage positive liability and responsibility within citizens to preserve the natural resources and enhance smart cities' sustainability. Usage of the concept of sharing economy in renewable energy within microgrids to improve energy consumption and support resilience systems (AkAnde et al., 2020).
The digital economy fosters digital involvement and engagement for citizens in all aspects of life and encourages digital industries and innovations. Supply chain applications, using IoT devices.	• Transformation of public services to the digital form in terms of business process and users' participation in all stages. • User awareness of cybersecurity risk associated with IoT applications.	Ensure that citizens are engaged, motivated, and skilled to utilize the smart city's provided digital services. (Carter, 2013). Underpadding risks from all aspects, not consider the standalone situation, and encourage understanding the connections and dependencies of different factors(Radanliev et al., 2019).
e-Commerce service applications, including mobile shopping applications	• Customer data privacy	Considering user's data privacy is essential, considering the balance between innovations and users' interests. (Kirimtat, Krejcar, Kertesz & Tasgetiren, 2020)

Table 3
Smart governance applications.

Forms of application	Issues\Challenges	Examples of Recommendations
Applications to allow users to control their devices within smart city.	Data security and privacy	• Provide decision-makers to grant access based on specific policies and guidelines to ensure users' data privacy (Ismagilova et al., 2020), (Kirimtat et al., 2020)
Illustrate social collaboration using Information and communication technologies.	Data security and privacy	• Adopting national policy considering the latest technologies and applications • Introduce intensive legal framework to increase public involvement (Čolić et al., 2020)
E-government projects and services	Stakeholders ability to cooperate and leadership support	• Interaction between people, policies, resources, culture and information technology to ensure success of provided services(Arroub et al., 2016)

Table 4
Smart Living applications.

Forms of application	Issues \Challenges	Examples of Recommendations
Smart Buildings	Data Security and privacy	Applying access control models encourages cryptography and state-of-the-art security architecture. (Vorakulpipat et al., 2021)
e-heath systems for smart assistance.	Data Security and privacy	Set specific standards for data security and privacy ((Elahi et al., 2019)
Home re-habitation applications	Data Security and privacy	Adopt transparency in implementing smart city 's applications(Nižetić, Šolić,. López-de-Ipiña González-de-Artaza, & Patrono, 2020)
Smart Tourism	Data Security and privacy	Innovative business models are required with enhanced security and privacy considerations(Kirimtat et al., 2020).

Table 5
: Smart Mobility applications.

Forms of application	Issues\Challenges	Examples of Recommendations
Internet of Vehicle for traffic safety	Sensor connectivity, network availability	Better integrated systems are used for better services (Porru et al., 2020).
Mobility as a Service, including demand transportation, smart ticketing.	Infrastructure, connectivity, security and privacy.	Develop infrastructure, enhance connections and consider security measures and ensure the existence of policies to govern data privacy(Paiva et al., 2021)
Road safety and smart surveillance systems	Infrastructure, connectivity, security, and privacy.	
Crowd assisted smart applications	Requires real-time connectivity and big data analytics	Use different big data analytical tools to predict peak periods and enhance provided services(F. Ullah et al., 2021)

of sensors such as radio frequency identification, integrated circuits, optical sensors, and pressure sensors to manage a smart city environment. The collected real-time data helps the decision-makers optimize waste and junk collection, recycling, and sorting. The authors illustrate that such understanding will improve the decision-making process regarding the city's logistics strategy and urban strategy.

A study by Nižetić et al. (2020) highlights the use of IoT technologies to enhance smart city waste management applications, including electronics waste in a manner that supports the circular economy concept. Table 7 provides examples of recommendations for smart environment applications challenges.

3.2. Risks related to smart cities

Smart city is an ecosystem that includes all aspects of human life, such as transportation, logistics, education, and maintenance healthcare, computerized to be controlled and accessed through smart devices. Each aspect is automated using different technologies and requires human resources and budget. Therefore, the development of smart cities also invites risks from multiple aspects (Ahad, Paiva, Tripathi & Feroz, 2020), (Coelho, Oliveira, Tavares & Coelho, 2021). In their research study, F. Ullah, Qayyum, Thaheem, Al-Turjman and Sepasgozar (2021) reviewed smart cities risks and grouped risks into three categories, technology-related risks, organizational risks, and external environment risks. The authors investigate the contribution of risks to smart city's governance and highlight 17 technology-related risks, 11 organizational risks, and 28 external environment risks. The authors propose a risk management framework based on this categorization and ranking of these risks based on a systematic literature review. Table 8 provides a

Table 6
Smart People applications.

Forms of application	Issues \Challenges	Examples of Recommendations
Education platforms Social platforms Engaging people with government (e-government platforms)	Data security and privacy	Consider the privacy of information and apply data protection legislation. Spread the awareness about smart city applications and educate the public about the benefits of having them(Allam & Dhunny, 2019).

Table 7
Smart Environment applications.

Forms of application	Issues\Challenges	Examples of Recommendations
Partnership applications between public and private sectors Public consultation in real-time Smart forestry applications	IoT devices connectivity, AI analytical tools, and their capabilities.	Enhancing the infrastructure of smart cities in terms of networks and connectivity. Develop robust AI applications for efficient data analysis and better performance.(Nitoslawski et al., 2019)
Waste management applications	IoT devices connectivity	Developing models for sharing infrastructure to reduce cost and increase data sharing between all waste management processes (Perera et al., 2014).
E- plants systems for plant monitoring and feedback	IoT devices connectivity	Solid planning for smart cities is crucial for better connectivity solutions (Nitoslawski et al., 2019).

summary of reviewed literature related to risks classifications.

The discussion on the risks associated with smart cities, both technical and non-technical, are discussed in the following sub-sections. The following sub-sections also address RQ3, which is related to the risks.

3.2.1. *Technical risks*

Technical risks are related to technology and its implementation, such as risks associated with IoT, big data, and AI as the most important ones. Based on their study on the consequence of technical verses non technical risks in smat cities, Singh and Helfert (2019) recommend dividing technical risks into three general categories: network coverage in the city, choice of technology, and discontinuation of technology. In addition, Ahad et al. (2020) mention that technical risks should consider security risks. Risks include cybersecurity, interactions between devices, systems, the absence of supporting infrastructure, unorganized data management, and adaptation of different standards in terms of technology and their integration. D'Amico, L'Abbate, Liao, Yigitcanlar and Ioppolo (2020), have discussed the challenges related to data quality and integrity, especially with the enormous amount of data generated from systems used in smart cities.

3.2.1.1. Technical risks associated with iot. Cybersecurity risk is a significant associated risk with IoT technology. As the number of connected IoT devices rises to support 'smart' ability in various sectors such as transportation, health, energy transmission, and others, its vulnerability towards information hacking and misuse also increases. Therefore, the smart city concept should be supported with measures for cybersecurity risk management (Lee, 2020);(Ande, Adebisi, Hammoudeh & Saleem, 2020).

Lee (2020) mentions that technical and managerial frameworks developed for preventing cybersecurity risks should also consider resource allocations. The author has proposed a four-layer framework to

Table 8
: Summary of risks classification.

No	Author	Technical Risks	Non Technical Risks
1	Ahad et al., 2020	Security risks, high adoption cost, interoperability between different IoT devices, lack of standards	Citizens' mindset and acceptance of digital changes; Natural disasters, such as floods and earthquakes, will affect the infrastructure of smart cities
2	Ande et al., 2020; Botello et al., 2020; Lee, 2020; Mohamed et al., 2020	Security issues related to IoT systems	
3	Arroub et al., 2016	Security and Privacy issues, Interoperability between IoT systems	Lack of standardized laws related to cybercrimes and cyber-terrorism
4	Atitallah et al., 2020	Security and Privacy facing IoT applications; Storing big data generated from IoT applications	Cost of infrastructure required to connect all smart city's systems
5	Baig et al., 2017	Cybersecurity, system misuse in smart energy systems	
6	Belanche-gracia et al., 2015; Caviglione & Coccoli, 2020; Ismagilova et al., 2020	Privacy and Security risks in smart city applications	
7	D'Amico et al., 2020	IoT Data Security, IoT Data quality and integration	
8	Elahi et al., 2019; Vorakulpipat et al., 2021	Privacy and Security risks of different smart systems	
9	Golubchikov & Thornbush, 2020	Cybersecurity and Data privacy in AI applications in smart cities	
10	Habibzadeh et al., 2019	Security and Privacy risks associated with smart city technological infrastructure	Policies and governance issues related to smart city technological infrastructure
11	Hamilton, 2020	Cybersecurity and Privacy risks	Lack of policies related to smart cities
12	Löfgren & Webster, 2020	Privacy and Security of big data generated from smart Cities systems	Quality standards for the smart city's data; Policies of data's ownership
13	Mehmood et al., 2017	Security, Privacy, and Trust risks of IoT systems; Interoperability risks; IoT systems connectivity risks	
14	Mikes, 2012	Operational risks	Legal, ethical risks; strategy risks; External risks: natural disasters
15	Neshenko et al., 2020; Sengan et al., 2020	Cybersecurity risks in smart city's systems	
16	Nitoslawski et al., 2019	IoT devices connectivity in smart environment applications	
17	Nižetić et al., 2020	Networking infrastructure risks, Sensors' technological risks	Lack of population education about smart applications
18	Paiva et al., 2021	Risks related to smart mobility Privacy; Data Integration and standardization	Environment risks affecting sensors' functionalities

(*continued on next page*)

Table 8 (*continued*)

No	Author	Technical Risks	Non Technical Risks
19	Perera et al., 2014	Risks of data privacy and security, Lack of standards	Social acceptance, legal issues related to security and privacy
20	Priyanka & Thangavel, 2020	Risks related to big data, in terms of data storage, ownership, security, and privacy	
21	Radu, 2020	Data Privacy risks	Environmental impact of e-waste, lack of society adoption risk
22	Singh & Helfert, 2019	Technology risks including data privacy and security; the interconnection between IoT devices; Risks related to network or discontinuing technology	Risks related to policies, regulations, and legal guidelines; Risks related to financial funding of smart cities projects; Risks related to approvals of projects' starting
23	Sovacool & Furszyfer, 2020	Privacy and Security risks for smart home applications; Devices Interoperability	Risks related to costs, and citizen's education and acceptance of technology
24	Ullah et al., 2020	Lack of standardization of Data risk; Data security and privacy	
25	Vidiasova & Cronemberger, 2020		Risks ignorance of citizens' perceptions and smart cities' stakeholders
26	Xie et al., 2019	Security and Privacy of smart cities' blockchain application, data storage risks	Cost of blockchain applications; Lack of regulations related to blockchain
27	Yigitcanlar et al., 2020	Data Security and Privacy related to Smart Cities' AI applications	Unethical recommendations generated by AI applications

help managers understand cyber risk management processes, including a procedure to calculate the cyber investment decision technique to lead to decisions based on calculations.

Habibzadeh, Nussbaum, Anjomshoa, Kantarci & Soyata, 2019 have studied cybersecurity situation in deployment of cyber -physical systems in smart cities . The authors mention that cybersecurity issues are not only limited to the IoT systems but can also happen due to sensors, networks, and smart city portals. The study proposes a smart box as a tool for different applications within smart cities, such as fire detection systems, power systems, and environmental systems, and identifies hardware and software architectures and policies to address cybersecurity issues. Other authors (see Mehmood et al., 2017; Sengan et al., 2020) mention that in order to obtain cybersecurity in city systems, the requirements, privacy, and security should be considered.

Sengan et al. (2020) mention that breaches in cybersecurity can lead to fake alarms such as fires, earthquakes, or circuit breakdowns, and this can endanger the public in the city. Therefore, for the use of IoT tools, governance causes and social aspects should be considered. Baig et al. (2017) suggest implementing relevant security controls to ensure safe data transfer within the smart city infrastructure and the cloud.

(Kandasamy, Srinivas, Achuthan & Rangan, 2020; Mehmood et al. (2017); Sovacool and Furszyfer Del Rio (2020)) highlight other related risks to IoT technologies: interactions between devices and systems, absence of supporting infrastructure, unorganized data management, unavailability of universal standards as related risks due to IoT technologies, and IoT ethical risks. Based on their study on e-health services, Zakaria, Abu Bakar, Hassan and Yaacob (2019) mention risks due to technical data and applications, infrastructure, and network and infrastructure. The authors provide a framework based on a standard framework, namely: Control Objectives for Information and related Technology (COBIT 5) because it focuses on the enterprise level and the IT domain. COBIT5 is supported by the Hospital Performance Indicator for Accountability (HPIA) to manage these risks.

Caviglione and Coccoli (2020) present the need for a holistic approach to include interdependence between all ICT-related actors: infrastructure, data space, and learning space to solve security risks. The study illustrates a framework applied to e-learning systems within smart cities considering all actors and developing an algorithm to detect privacy issues from the design phase of a course.

3.2.1.2. Technical risks associated with ai. Allam and Dhunny (2019) mentions that there are security and privacy risks associated with AI applications. Yigitcanlar, Desouza, Butler and Roozkhosh (2020) mention system complexity, which is related to associated technical risks with AI technologies. These risks may create legal issues and require many verifications of compliance with existing laws related to fundamental rights protection. Yigitcanlar et al. (2020); Yigitcanlar et al. (2020) investigate the Artificial Intelligence (AI) role in smart cities, businesses, and society. The authors illustrate AI applications, mainly related to data analytics in energy, education, health, security, transport, sustainable environment, and urban areas management. AI methods are used to develop investigation applications, motion detection, and forecasting analysis. The authors mention that a good communication network monitoring system resulting from such an application can lead to early recognition of threats, frauds, crimes, fires, and accidents. Yigitcanlar et al. (2020) discuss AI paradigms available in the literature, including machine learning, search and optimization, and logic-based. The study highlights the AI contribution to enhance different smart city dimensions. However, there are risks associated with AI, as mentioned in Table 9.

Recent studies by (Botello et al., 2020; Priyanka & Thangavel, 2020; Yigitcanlar et al., 2020) **studied smart city services by considering privacy and security risks**. The authors mention that integration of blockchain and other encryption technologies with AI can help to define asymmetrical behavior, identify the threat, and control it rapidly to assure data security within the smart city system. Golubchikov and Thornbush (2020) study AI and Robotic applications in some smart cities worldwide such as Moscow, Toronto, Ottawa, Hong Kong, Dubai, Sydney, New York, and London and provide cybersecurity and data privacy related risks due to the AI. The authors recommend a broader coverage of the socio-technical system to benefit from AI applications in smart cities.

3.2.1.3. Technical risks associated with blockchain. Botello et al. (2020) study the problem related to smart city services' security, and present blockchain technology as a solution for security challenges related to IoT technologies. Blockchain technology is based on a point-to-point decentralized network where all transactions are validated by registered nodes and stored in a central ledger. This characteristic of blockchain is utilized to build a network that will enhance data security within the IoT system. The study proposes a framework to manage security events created from several IoT devices with integrity and acknowledgement.

Xie et al. (2019) study block chain technology challenges and opportunities to illustrate the applications of blockchain technology within smart city's dimensions and the associated risks with the technology, including security and privacy, low productivity, storage, and energy consumption efficiency. The authors mention that challenges of blockchain technology needs to be addressed to use this technology adaquetly with smart city applications. Some of the applications of blockchain on smart city dimensions and main risks are given in Table 4. In addition, the study of (Xie et al., 2019) highlights the cost risk of implementing and operating blockchain technology. Blockchain technology is

Table 9
Associated Risks with AI Applications in Smart Cities.

No	Smart city dimension	AI applications contribution	Associated risks	Reference
1	Smart Economy	• Automated data management and analysis will enhance productivity and innovation • Pattern recognition will reduce costs and increase resources • Analyzing big data from multiple resources will improve decision-making • Reaching to conclusion using logical reasoning	• Cybersecurity and data privacy	• (Yigitcanlar, Desouza, Butler, & Roozkhosh,2020)
2	Smart living	• Enhance health monitoring • Improve health diagnosis • Provide independent and interactive tutoring systems.	• Data privacy and protection	• (Yigitcanlar, Desouza, Butler, & Roozkhosh,2020)
3	Smart Environment	• Monitor environmental changes • Optimize energy consumption and production • Enhance functional operations of smart transport systems	• Cybersecurity	• (Yigitcanlar, Desouza, Butler, & Roozkhosh,2020)
4	Smart Governance	• Enhance surveillance systems operations • Aid disaster management • Increase citizen's contribution to decision-making	• Cybersecurity	• (Yigitcanlar, Desouza, Butler, & Roozkhosh,2020)
5	Smart People	• Enhance Knowledge sharing applications • Improve learning and teaching tools	• Data Privacy and protection	• (Radu, 2020)
6	Smart Mobility	• Improve predictions of traffic status, road conditions, and streetlights	• Security and Privacy	• (Paiva et al., 2021)

Table 10
Associated Risks with Blockchain Applications of Smart Cities.

No	Smart city Dimension	Blockchain Applications	Associated risks	References
1	Smart Living	• Smart health applications for healthcare providers and medical researchers as a storage repository for chained medical data • Medical data access control to ensure access for authorized users	• Data security and privacy	• Xie et al., 2019
2	Smart Environment	• Storing Electricity consumption information using smart contracts to enable automatic payments.	• Data security and privacy • Low productivity	• Xie et al., 2019
3	Smart Mobility	• Implementing a decentralized smart transport system • Facilitate electricity trading for electric vehicles using Blockchain smart contracts	• Data security and privacy • Energy consumption efficiency	• Xie et al., 2019
4	Smart Economy	• Sharing services using blockchain-based technology to ensure availability, confidentiality, and integrity	• Low productivity	• Sun et al. (2016).
5	Smart Governance	• Decentralized governance tool for smart cities to manage digital assets using blockchain technology.	• Data security and privacy	• Coelho et al. (2021)
6	Smart People	• Smart social communication applications using blockchain technology to avoid cyber attacks	• Data Privacy	• Sadik, Ahmed, Sikos, & Najmul Islam, (2020)

developing, and studies are still investigating the operational cost for the smart city's blockchain-based applications.

Furthermore, Coelho et al. (2021) illustrate the use of blockchain technology to create decentralized governance platform for smart cities to disseminate transparency concerning privacy and cost-efficiency. The study suggests this platform will minimize security and privacy risks, defined for smart cities' applications.

3.2.2. *Non-Technical risks*

Ahad et al. (2020) mention that risks in smart cities are not limited to technical risks. The comprehensive analysis of the study demonstrates that non-technical risks have a noticeable effect on the implementation and the operation of smart cities. Löfgren and Webster (2020) in their study, highlighted issues related to governance, legal and organizational differences between public and private sectors in smart cities. The following sections provide discussion on non-technical risks: socioeconomic risks, governance, and legal and strategy risks

3.2.2.4. socioeconomic risks. socioeconomic risks include the traditional mindset of stakeholders and decision-makers. Implementing the smart city concept means handling multidisciplinary projects that require a considerable budget, trained personnel, and technology exposure of the citizens, decision-makers, and professionals. Meadowcroft, Stephens, Wilson and Rowlands (2018) discuss social risks in terms of the public proposition of specific technology, such as Ontario's Wind energy rollout and the use of nuclear power in Germany. In terms of smart city applications, the authors mention the need to examine social struggles on smart grids and the future of electricity systems because these systems involve different actors: regulators, customers, technology companies, energy service providers, etc., for better efficiency, sustainability and cost control.

Vidiasova and Cronemberger (2020) examine the risks associated with the ignorance of citizens' perceptions and other stakeholders' participation in smart cities. Weak public engagement affects smart city's ability to offer increased quality of life and efficiency

Kummitha and Crutzen (2019), the present socioeconomic risk that highlights the effect of the culture of failure assumptions on entrepreneurial activities related to IoT. This may result in the reduction or rejection of these activities, especially with the lack of institutional support for smart city innovations by individuals due to associated risks with such initiatives.

3.2.2.5. Governance and legal risks. Singh and Helfert (2019) show that smart city projects face governance risks in terms of socio-political risks associated with policies, laws, rules, and political and social force. Concerns related to approvals of smart city projects, competence in their monitoring, resource management, and stakeholder management are some of the factors that should be considered in governance. Vidiasova and Cronemberger (2020) highlight the risk of the extent to political leadership advance in solving technology involvement. Low levels of leadership advance will result in decreased intentions to sponsor smart city's projects and endanger the sustainability of current smart cities.

Singh et al. (2020), Xie et al. (2019), and Hamilton (2020) consider legal issues related to data privacy, data protection risks within the smart city projects. The authors mention that security and privacy issues become prominent when the legal system is not updated to address the issue of technology use, integration, and dissemination of information. The use of closed-circuit television in the city, automated bank teller machines, city coverage with wireless frequency, e-payments and transactions, and collection of personal information can be some examples of legal instruments to be established with the need to thorough analysis. Therefore, adequate features should be established to assure the public of security and privacy of data and legal procedures in support of the victim in case of a breach. Löfgren and Webster (2020) recommend creating ethical standards in relation to data privacy in smart cities, clear ownership policies for data and approved standards for data storing, protection and safety, to prevent governance and legal risks.

3.2.2.6. Strategic risks. Strategic risk in smart cities emerges when the strategic approach lacks the link between urban ICT development research agenda and sustainable development research agenda. The lack of this linkage will waste investments made in ICT, increase environmental and socioeconomic concerns (Bibri & Krogstie, 2017). However, the authors mention that city management needs to discuss strategic risks and challenges in strategy formulation and implementation. However, the authors do not explicitly define strategic risks in smart city projects or smart city administration. The suggested framework is generalized for organizations in identifying any unavoidable risks related to the organization's strategy and operation.

3.3. Risks analysis and assessment tools

Risk analysis starts with identifying technology choices and their alternatives, strategies, causes of risks, responses, consequences, indistinctness, and contingency plans to reduce the ambiguity of risks (Ward & Chapman, 1991). However, risk management in a smart city is not adequately addressed, possibly due to time or financial constraints (Pimchangthong & Boonjing, 2017).

The risk management process is essential to enhance project performance. This enhancement is achieved by governing and monitoring the effects of uncertain and risky events on project objectives. Risk management includes risk identification, analysis, assessment, prioritization, and responses (Islam et al., 2017). Risk management strategies are crucial for projects' success; research studies evaluate these strategies without considering uncertainties (Edjossan-Sossou et al., 2020). Edjossan-Sossou et al. (2020), in their study, highlighted the need to consider uncertainty and combined fuzzy AHP method and Fuzzy weighted mean methodologies to assist decision-makers in choosing a resilient risk strategy for their project.

As shown in Fig. 3, understanding dimensions and associate technical and non-technical risk is essential. For the successful implementation and achievement of smart city objectives, risk assessments should be continuously performed. For such an assessment, appropriate tools become necessary. The outcome of such tools can be used to develop a risk response strategy related to each smart city dimension. As the smart city is multidisciplinary, the best approach would be to associate risks for each project in each dimension independently (Helfert, Krempels, Klein, Donnellan & Gusikhin, 2015). The following sections highlight general smart city assessment (SCA) tools and risk assessment tools used in smart city projects, addressing RQ4 in detail.

3.3.1. Smart city assessment tools

Fernandez-Anez, Velazquez, Perez-Prada and Monzón (2018) present Smart City (Project Assessment Matrix) -SC(PAM) -as a general risk assessment tool for smart city projects. The authors use project actions corresponding to the smart city dimension to formulate the matrix in the assessment tool. Patrão, Moura and Almeida (2020) illustrate SCA tools developed over the last decade to assess the smartness of cities. Each tool considers different indicators due to the different definitions of smart cities. The study summarized indicators based on international standards: ISO 37,120 non-mandatory standard measures city services and quality of life, ISO 37,122 measures sustainable development in smart cities, ETSI indicators used for the performance of digital multi-service cities, ITU 4901 key performance indicators (KPI) to measure the use of ICT in sustainable smart cities, ITU 4902 KPI to measure the impact of using ICT in sustainable smart cities, and ITU 4903, and UN SDG 11+ indicators to assess the achievement of UN sustainable development goals in smart cities. The study listed the tools compared by Sharifi (2019) and concluded that these tools could be developed and information technology can be used to assess the indicators used in these tools.

Sharifi (2019) provides a comparison of 36 SCA tools. Some examples of the examined tools are Lisbon ranking for smart, sustainable cities; cities in motion index; global power city index; innovation cities index, IoT-enabled smart city framework, and the UK smart cities index., the tools are examined in terms of comprehensiveness of considering smart cities' indicators, engagement of different stakeholders, flexibility, interoperability, feasibility, and plans. The study presents a lack of balanced distribution of indicators within the assessed tools, weak stakeholders engagement; local conditions are not considered, the linkage between assessment results and action plans is not mentioned in the majority of tools. Also, in another study Sharifi (2020), investigated indicators of smart cities dimensions that can be used in smart city assessment. Patrão et al. (2020)) mention that the SCA tools used in Sharifi (2019) are static, and there is a lack of balance to use them in different city sizes, specific needs of the cities, engagement of stakeholders, and the evaluation of UN Sustainable Development Goals (SDG).

Deveci, Pekaslan and Canıtez (2020) develop an approach for the theoretical assessment of smart cities from eight dimensions, namely: Management and organization, governance, technology, economy and finance, sustainability, data analytics, community engagement, and institutional context. The authors build an extensive decision-making framework. The approach is Interval Agreement Approach (IAA), which is used to arrange and assess smart city dimensions. The study provides testing results, and the finding proves beneficial decision-making processes for researchers and experts dealing with smart city implementations. Westraadt and Calitz (2020) study Integrated city management platforms, to develop a framework for smart city management and planning considering all applications and their relations. The resulting framework was tested on crime detection and provided satisfactory results, yet needs to be tested in water, transportation, and other smart applications.

3.3.2. Risk assessment tools

Risk assessment is essential to overcome the challenges within a smart city's project. Different studies have highlighted risk assessment tools; however, they are related to a specific example of a specific technology group. Namazian, Yakhchali, Yousefi and Tamošaitienė (2019) use a combination of Monte Carlo Simulation and Bayesian Networks Methods to assess the project's completion time when the project is at risk. The study highlights that studies related to risks lack assessing risk relations and deal with each risk individually.

Jamshidi, Rahimi, Ait-Kadi, Rebaiaia and Ruiz (2015) propose a framework connecting Fuzzy failure mode and effects analysis (FMEA) and gray relational analysis (GRA) to analyze risks of enterprise resource planning (ERP) projects. The study provides approaches for quantifying the unfavorable impacts of risks on component failure and the probability of system failure.

FMEA is a technique that evolved to avoid failures. The main advantage of FMEA is in evaluating the critical potential risk in order to support risk management in a project (Domingos, Rita, Terra & Ignácio, 2008). Subriadi and Najwa (2020) use improved FEMA as an ICT risk assessment approach. The improved FEMA has four main phases: determining risk assessment requirements, identifying risks, assessing risks, and analyzing and evaluating risks. The exact parameters used in this technique are based on the risk impact category and are aligned to the failure effect. The used parameters are risk severity and occurrence time. The study concluded that the improved FMEA provided more consistent results and risks assessed efficiently.

Dimitriadis, Flores, Kulvatunyou, Ivezic and Mavridis (2020) provide a combination of OCTAVE and MAGERIT approaches to develop risk management tools for ICT and specifically for cybersecurity. The authors suggest an automated risk estimation in smart sensor environments (AERS) that adjusts the business process model of life cycle management with the utilization of available standards and platforms. The authors mention the use of attack patterns to extract the model for automatic evaluation of risks in computerized systems. The authors cite the main advantages of such a system are to helping organizations in identifying operating assets within the business process and their associated risks, thus conducting risk assessment consistently according to the business needs and increasing incident response readiness.

Another study by Ullah (2018) focuses on risk assessment for underground applications in smart cities, including underground railways, water supply systems, sewerage systems, parking, and electricity lines. The study aims to create one risk index for all systems, although each system can have different risk factors and different indices. The author used three models to create and measure the generated final risk index: linear approximation, hierarchal fuzzy logic, and a hybrid model based on a combination of both models. The author mentions that the hybrid model provides an efficient estimation for the final risk index. The resulted model can be used to perform automatic clustering based on the risk index and assist maintenance teams in prioritizing their tasks. The author highlights the need for further exploration in advanced methods of risk estimation and assessment.

Alawad, An and Kaewunruen (2020) investigate smart risk assessment methods in railway applications. The authors introduce a risk assessment framework called an intelligent system for managing risks (ISFMR) to increase security and safety and to assess and manage risk effectively. The study uses an adaptive neuro-fuzzy inference system (ANFIS) as a model to enhance risk management. AI trained through artificial neural networks (ANN) is used to predict risks and uncertainties based on real values and risk information. This increased the accuracy in the risk level performance predictions in learning, making predictions, and capturing risk level values in real-time. However, the authors cite the limitation as the time needed for machine training and the consideration of linearly of input parameters in the risk assessment tool.

Risk assessment for IoT medical devices is discussed by (Kandasamy et al., 2020) by considering the cyber risks. The authors suggested a method that uses a risk vector for each medical IoT device, which can provide risk rank based on the weight for the impact and support the management of cybersecurity risks in medical devices.

Other studies such as Franchina& Socal, (2020) review risk assessment tools and platforms, such as DOMINO, a tool developed by Ecole Polytechnique de Montreal that depends on risk consequences analysis to model risk spreading warn the management on its effects. Also, the authors describe other tools such as the foresight tools for responding to cascading effects in crisis (FORTRESS) and GRASSP Geospatial Risk and Resilience Assessment Platform (GRASSP) to analyze and simulate critical infrastructure. The authors concluded that these tools are complicated and require knowledge of hardware and software. Their study suggested another model based on (What-if) methodology, which relies on human experience to obtain the risk-related outcomes.

4. Discussion

Smart city is generally considered as a buzzword in many countries to indicate the use of technology for some of their governance processes. As mentioned in this review, there are multiple dimensions to be considered in order to obtain 'smart' outcomes for a city. Smart outcomes, however, need the right use of technology and the governance processes, and the participation from different sectors of society. The use of technology, integration systems, and governance, however, can invite both technical and non-technical risks. Such risks may not be understood well by the planners, and it can lead to misperception of smart city applications and advantages. The capability to design the smart city ecosystem and the ability to integrate it with a better risk management process can support the objective of a smart city. This review focused on highlighting the opportunities and risk-based challenges related to smart cities. Four research questions were developed to understand the content of the reviewed literature and are discussed next.

The first research question was focused on the type of dimensions of the smart city as considered by most of the literature. The review reveals six main smart city dimensions. Almost all of the authors consider these dimensions and mention that they must be carefully integrated into the city processes through planning, design, and operation.

The second research question was focused on the applications associated with each smart city dimension. The review shows that such applications are designed to enhance efficiency and to increase the quality of life in each dimension. Applications such as online economy platforms, digital economy, and the sharing economy are related to the smart economy dimension. E-government applications and services, public participation platforms are related to smart governance, and smart people dimensions Healthcare applications (e-health), education applications (e-learning), and smart building applications are considered for smart living. Similarly, smart mobility applications concentrate on transportation systems and smart vehicles, whereas smart environment dimension-related applications consider waste discarding, pollution control, energy management, smart grid quality of air and water, increases in green spaces, and monitoring emissions.

The third research question was focused on the types of risks related with smart applications. The review shows that there are both technical and non-technical risks involved in smart city design and operation. Most of the focus in literature is in technical risk. This can be obvious as smart city is usually understood in terms of the utilization of smart technologies and systems. Although very few researchers focus on non-technical risks, it is emphasized that addressing non-technical risks such as social, economic, governance, legal, and strategic risks can improve the outcomes of smart city implementation and operation. Therefore, the aspirants of smart city implementation may have to analyze their non-technical part, like streamlining the governance system, facilitating the implementation through a strong legal system that can preempt and articulate risks implications and dynamically support the continued operation of the city.

The fourth research question was focused on the available risk assessment tools and techniques that are explicitly used for risk assessment and management in smart cities. The review shows that there are only a limited number of risk-related tools that are designed explicitly for smart cities. However, these tools are designed for a specific application within one dimension and lack holistic handling of different types of risks in all dimensions. This shows that there is a lack of understanding of the risk impact in smart city applications, and this is the reason why there are only a limited number of risk assessment frameworks. The lack of a good risk analysis framework hinders risks mitigations and management (Neshenko, Nader, Bou-Harb & Furht, 2020).

Discussed results are substantial to develop enhanced risk assessment tools and techniques for smart cities, professionals interested to understand smart cities dimensions and students who would start research projects related to smart cities.

The following section will highlight future research opportunities and review conclusions.

5. Conclusion and future research

The planning and implementation of smart cities concepts are considered complex and multidisciplinary that need to consider multiple dimensions. The review identifies the dimensions through the literature analysis. It is to note that not all smart city examples apply all the dimensions, but they consider the influential impact of some of the dimensions in order to achieve their objectives. The review also indicates that the level of technological applications also varies. Due to the use of ICT and related technologies, the level of risks, especially related to security, privacy, and safety, becomes important. The review also shows that smart city faces both technical and non-technical risks. The level of risks and complexity of their management changes over time due to the development of technology and processes. Therefore, continuous monitoring and risk assessment of each of the smart city dimensions and smart city as a system becomes important. The review further shows that although there are sporadic developments in risk management tools, they are not comprehensive enough to address the risk issues faced by smart cities.

5.1. Future research

Based on the review of the paper, there would a few research directions that can be taken up in smart city research. Some of the concepts for further research are given below.

IoT is the dominant technology used for smart city applications in different dimensions. Researchers like Deveci et al. (2020); Patrão et al. (2020); Sharifi (2019) highlight IoT usage in transportation, health, energy transmission, waste management, and others. However, cross-dimension integration of IoT and using the data obtained in emerging technology such as AI and blockchain technologies in order to enhance different smart city dimensions is still lacking (Yigitcanlar et al., 2020). This type of research can focus on overcoming major cybersecurity and privacy challenges in smart cities (Sun, Yan & Zhang, 2016).

The research shows that the implication of non-technical risk on the success of a smart city is underrepresented. It is possible that non-technical risks are more complex and focus on human behavior, which is unstable and can react differently in different situations. Therefore, it is necessary to mitigate the impact of such risk and to reduce the opportunity to trigger such risks. Therefore, further research can focus on the understanding of the different types of non-technical risks and their implications on the smooth operation of smart cities. This will also require research on the development of risk management techniques that are suitable for smart cities and flexible enough for application in different types of smart cities. A smart risk assessment tool can enhance the secured performance of systems in a smart city.

Fernandez-Anez et al. (2018); Patrão et al. (2020), and Deveci et al. (2020) introduce different tools to assess smart cities in terms of operation smartness, sustainability or management. Sharifi (2019) compared different tools and identified weaknesses and strengths. As per the recommendations by these authors, further research can focus on developing better smart city assessment tools that can be suitable for assessing smart cities dimensions in a holistic view and using the needed measures for increasing performance.

Dimitriadis et al. (2020), Domingos et al. (2008), and Alawad et al. (2020), mention that the available risk assessment and management techniques are not holistic. The available tools lack adequate consideration of non-technology-related risks; the studies highlight consideration of technology-related risks independently without considering non-technology-related risks (Singh & Helfert, 2019). Also, it is crucial to consider all dimensions and their interrelations, since these dimensions are not separated in reality (Zheng, Yuan, Zhu, Zhang & Shao, 2020). Therefore, comprehensive research on the risk factors, their individual assessment methodologies, and technology and non-technology-based risk management becomes necessary. Such a methodology can use AI-based and blockchain-based technology as they can be used for the prediction, trigger identification for autonomous, semi-autonomous, or manual intervention to resolve them. As a smart city is an enterprise at its foundation level, the enterprise architecture approach, as mentioned in Singh and Helfert, (2019) and Yorgos, Golias, Dedes, Douligeris and Mishra (2019), can be considered for further research. Such an approach can help to develop a robust enterprise risk management approach that can be used with some adjustments in different smart city environments.

CRediT authorship contribution statement

Reem Al Sharif: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Shaligram Pokharel:** Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that there is no conflict of interest withany one .

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