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Towards smart and sustainable city: Innovative Solutions for Integrating Modern Technologies to Address Climate Challenges and Achieve Resilience and Efficiency in Small and Medium Urban Areas in the Arab World.

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Abstract

Background: Smart cities are among the most important global trends aimed at enhancing their ability to cope with emerging challenges. This research aims to study sustainable smart cities as a modern trend that can deal with climate change and enhance urban resilience and efficiency in small- and medium-sized cities in the Arab world. Method: This study adopted a descriptive approach based on a review of the relevant literature. Results: According to this study, sustainable smart cities integrate modern technology into the urban structure and rely on six dimensions: smart mobility, smart environment, smart people, smart governance, smart living, and smart economy. Moreover, sustainable smart cities use many modern technologies, the most important of which are the Internet of Things, deep learning, big data, multi-clouds, cognitive computing, smart automation, blockchain, and cybersecurity. On the other hand, smart cities help enhance adaptation to climate change. They contribute to enhancing the urban resilience for rapid recovery from disturbances and other dangerous phenomena. Conclusion: Adopting a smart-city approach enhances the resilience of cities to climate change. However, there is an urgent need for further studies on Arab cities' readiness to implement this approach and to identify the obstacles that prevent it so that they can be addressed within plans.

Keywords: Smart and Sustainable city, Modern Technologies, Climate Challenges, urban Resilience and urban Efficiency.

1. Introduction

Climate change is one of the most important global issues, and it occupies a large space in international conferences. These conferences focus on reducing the percentage of toxic emissions that cause global warming (1).Climate change negatively impacts the natural and built environment, putting significant pressure on resources, increasing the risk of pollution, threatening food and water security, and causing disastrous economic consequence (2) .

To tackle climate change and other natural phenomena or human-made hazards that threaten the stability of urban environments and their ability to provide a livable environment, it is necessary to enhance the resilience and effectiveness of urban areas. Essentially, resilience improves urban areas' capacity to adjust to obstacles, disruptions, and emergencies, hastens their recuperation, and minimizes possible harm(3).

Numerous development trends have emerged to achieve urban resilience and enhance the effectiveness of cities in addressing various challenges. One effective way to enhance urbanization is through sustainability(4). Consider the significant advancements in technology (3,5,6), argue that integrating modern technology and creating smart cities would enhance the resilience of urban areas to face various challenges, especially environmental ones. Accordingly, the study's idea arose to explore the trend towards establishing sustainable smart cities that can address climate change and enhance urban resilience and effectiveness in small and medium urban areas in the Arab world.

Today, the world faces increasing risks from climate change as the planet's temperature rises at an unprecedented rate, resulting in resource depletion and high levels of toxic pollutants. Consequently, urban areas become unlivable. Smart, sustainable cities represent a crucial modern concept that serves as a strategy to address these challenges and enhance the quality of life for residents. Nevertheless, there are diverse opinions regarding the various effects that smart, sustainable cities can achieve. Therefore, the study aims to investigate the trend towards smart, sustainable cities as a means to address climate change and improve urban resilience and efficiency.

The study contributes to the creation of theoretical knowledge about sustainable smart cities. This concept remains a contemporary field that requires further investigation. On the other hand, the study can open more horizons to explore the possibility of establishing smart and sustainable Arab cities and investing them in solving urban problems such as food security, water security, unemployment, traffic congestion, and other urban challenges. Therefore, this study aims to identify the concept and dimensions of sustainable smart cities, describe the contemporary technologies utilized in sustainable smart cities, identify the role of sustainable smart cities in dealing with climate change and, identify how sustainable smart cities can improve urban resilience and effectiveness.

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2. Methodology

The study adopted the descriptive approach by reviewing the literature related to sustainable smart cities and their role in adapting the urban environment to potential challenges.

3. Result

Bouzguenda et al. (7) aimed to identify the contribution of technology in creating smart and sustainable cities. To achieve this, the study employed a systematic review approach, conducting a critical analysis of the content of a group of studies. Accordingly, the review confirmed that information and communication technology, as well as digital citizen participation in the urban context, lead to the creation of smart and sustainable cities.

Furthermore, Wahba (8) sought to identify the technologies used to collect the data needed to create smart cities. The study adopted a descriptive approach based on a review of relevant studies and research. The study demonstrated that cities are undergoing extensive technological transformations, leading to the incorporation of technologies from the Fourth Industrial Revolution into the urban environment and infrastructure design. Furthermore, smart cities are characterized by a connection between physical spaces and city management systems on the one hand, as well as between citizens and the government on the other. On the other hand, the study indicated that big data analysis and the Internet of Things provide a type of social contract concluded between local government, companies, and citizens.

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Additionally, the incentive feedback system provides an opportunity for each category to participate in providing innovative solutions that address urban challenges.

In light of urban challenges, especially population growth, Okonta & Vukovic (6)explore how to leverage ICT to enhance urban resilience and sustainability and improve the quality of life of residents. We evaluated fifteen smart city initiative applications, including the Internet of Things, urban mobility, energy management, employee engagement platforms, and other applications related to sustainability and resilience. We also conducted a thematic study of thirty cases that intersect with resilience and sustainability. The study results indicated that urban expansion causes many urban problems, such as traffic congestion, disasters, environmental degradation, social participation, and economic disparities. Smart city applications such as the Internet of Things and citizen engagement platforms contribute to addressing these challenges. These applications are also consistent with the six smart city work areas (governance, mobility, environment, people, living, and economy).

On the other hand, Aldegheishem (9) assesses the level of achievement of the concept of smart cities in some cities in the Kingdom of Saudi Arabia (Riyadh, Mecca, Jeddah, and Medina). A review of the literature and previous studies identified seventy-five indicators, which formed the basis of the evaluation process. The Kingdom of Saudi Arabia applies these indicators in its smart city initiative across six fundamental dimensions: economy, society, environment, quality of life, mobility, and governance, with the aim of improving quality of life and promoting environmental sustainability. The study's results indicate that the four cities have made significant progress in implementing smart city indicators, with Riyadh achieving the highest level of advancement in the smart city initiative.

In his 2024 study, Narain (10) explores the potential of integrating smart city technologies into a strategic framework to promote urban sustainability, focusing on leveraging the Internet of Things (IoT), data analytics, and digital infrastructure. The study highlights the significant impact of these technologies on urban innovation, resilience, and sustainable growth through a case study approach. It emphasizes the importance of incorporating information and communication technology (ICT) into urban development processes to design smart, sustainable cities with high livability standards.

In another study, Rajković and Okour (11) explored mechanisms for enhancing resilience in urban environments to address climate change challenges through a systematic review of eighteen studies on climate change and its response mechanisms. The literature on climate change covered four main academic areas: environmental sciences, engineering, risk reduction and disaster management, and social sciences. The study found that resilience is often a key tool for recovery and developing effective responses to climate risks and climate change in the built environment.

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In a related context, recent studies indicate that smart cities rely on the use of information and communication technologies (ICT) for urban design and management, which enhances urban resilience. The research confirms that the application of these technologies strengthens cities' ability to adapt to and effectively manage urban challenges.

3.1 Smart Sustainable Cities

The world has witnessed numerous environmental, social, and economic crises since the mid-20th century. These crises have prompted countries since the beginning of the 21st century to engage in various trends related to improving the quality of the built environment, raising the level of services, and improving infrastructure. These efforts improve city attractiveness, quality of life, and ability to respond to urban challenges (12).

In conjunction with the information technology revolution, the concept of the smart city appeared, which refers to cities with a built structure and infrastructure integrated with information and communications technology, where they are coordinated and managed through digital technology (13).

The term "smart cities" was first introduced in 1994, gained widespread use in urban literature and initiatives by the beginning of the 21st century. Despite its widespread use, there remains no specific definition for smart cities(9), leading to a variety of definitions, the most simple being "the convergence of technology and the city" (12)

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Bakıcı et al. (14) defined smart cities as high-tech urban areas that connect residents and urban elements through technology to achieve sustainable development and enhance the quality of life. Furthermore, Giffinger et al. (15) characterize smart cities as those that employ innovative smart solutions to improve the quality of services offered to their inhabitants. Kourtit & Nijkamp (16) assert that innovative cognitive-technical strategies, aimed at enhancing the social, economic, environmental, and competitive value of urban areas, give rise to smart cities. According to the previous definitions, smart cities integrate technology with urban environment elements to improve sustainability, enhance quality of life, and achieve economic gains.

The literature on smart cities discusses the concept of sustainability in various ways, with some studies making a distinction between the two concepts. Proponents of this view argue that the relationship between intelligence and sustainability is not definitive, as some smart cities focus more on technological and economic profitability rather than achieving actual sustainability goals (12). As a result, some smart cities may fail to achieve (17). On the other hand, those who believe the two concepts are closely linked argue that smart cities aim to achieve sustainability, with the use of technology in this context addressing environmental challenges and enhancing quality of life (9).

Given this, it becomes crucial to associate the concept of intelligence with the pursuit of sustainability, as the value of smart cities largely depends on their sustainability.

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In other words, the integration of modern technologies with elements of the urban environment must aim to achieve environmental, economic, and social sustainability. Accordingly, sustainable smart cities are those that aim to integrate advanced technologies into their infrastructure to meet the needs of their current residents while ensuring the ability of future generations to meet their own needs.

On the other hand, six fundamental dimensions (elements) are associated with smart cities: smart economy, smart mobility, smart environment, smart people, smart living, and smart governance (18), which illustrate as following:

- **Smart economy:** It is able to combine production, innovation, and entrepreneurship so that it can bear the costs of meeting the needs of the population, achieving integration with global markets, and enhancing competitiveness. Information and communication technology in the smart economy facilitates electronic commerce development and streamlines commercial operations and transactions, including government permits (19).
- **Smart mobility:** It refers to new solutions to provide an efficient and clean transportation network that improves the efficiency of urban transportation operations and enhances the quality of services provided to residents. Integrating technology into transportation infrastructure helps improve the efficiency of urban transportation, enhance accessibility, reduce traffic congestion, and lower toxic emissions. The smart transportation network relies on a variety of sustainable transportation forms, such as public buses, bicycles, shared cars, and other multimodal transportation(6,8).

- **Smart environment:** It is a reflection of natural factors, pollution levels, and resource management. A smart environment is defined as using modern technology to activate recycling processes, use renewable energy sources, improve resource and waste management, reduce the carbon footprint of buildings, and manage their energy consumption. Additionally, the integration of digital technologies lessens the influence of climate phenomena (20).
- **Smart people:** This dimension pertains to the population's involvement in shaping a smart urban life, generating innovative ideas and solutions, and improving communication among the public and private sectors. To achieve this, it is necessary to provide equal learning opportunities, with a focus on distance learning and online digital training courses. This improves the population's educational credentials, fosters their creativity, and expands their exposure to the external world(21,22).
- **Smart living** :Smart living aims to improve the quality of life of residents by creating a livable urban environment that enhances the well-being of residents, improves public safety and health, and improves social interaction (6). Technology can create a system that can monitor human health indicators and provide healthcare services. In addition, some modern technologies help in creating new lifestyles or improving existing ones(19).
- **Smart governance:** The concept of smart governance pertains to the degree of interaction among the government, the population, business owners, and

civil society institutions. Alternatively, it refers to the degree of political engagement and the population's input into the process of making decisions and developing public policies and strategies. Smart governance works to provide citizens with data and digital services to meet their needs, as well as transparent and reliable communication channels with governments and official bodies (6,19).

The integration of the six aforementioned dimensions leads to the creation of smart cities. Investments in human and social capital, along with modern and traditional communications infrastructure, can amplify the presence of these dimensions. These investments not only promote sustainable economic development but also enhance high-quality lifestyles supported by participatory governance and effective management of natural resources(23).

3.2 Modern Technologies in Smart Sustainable Cities

Information and communication technology sets sustainable smart cities apart from other types of cities. Okonta & Vukovic (6) suggest that smart cities integrate three layers of technology: software, infrastructure, and digital data. Infrastructure connects digital data and software. Digital data is the data collected from all parts of the city through sensors and communication networks. Infrastructure, on the other hand, provides the tools necessary to make this data available. Software processes the data and converts it into useful, usable information, such as smartphone applications that determine public transportation schedules, locations, and estimated arrival times based on traffic congestion and other factors.

Digital technologies such as the Internet of Things, big data, and artificial intelligence play a pivotal role in enhancing the services provided to residents, thereby improving their quality of life and well-being. These technologies help in collecting and analyzing data, generating predictive visual insights that support decision-making and guide development policies. They also contribute to improving public health and safety, mitigating the environmental impact of urban expansion, and promoting environmental sustainability. Additionally, they foster economic growth, encourage innovation, and create new opportunities for investment and entrepreneurship. On the other hand, sustainable city technologies enable the principles of transparency and participation in urban policymaking, while upholding values of equity and inclusion. Moreover, these technologies help enhance the resilience of cities, preparing them to face future challenges such as climate change, pandemics, natural disasters, and more(10).

Studies indicate a range of advanced technologies used in smart cities, such as the Internet of Things, deep learning, big data, multi-cloud computing, cognitive computing, intelligent automation, blockchain, and cybersecurity (24). The Internet of Things helps in collecting data through its interaction with sensors and smart applications(25). For example, the Internet of Things can reduce energy consumption in transportation systems by managing lighting and air conditioning in buses and reporting any malfunctions (26). Deep learning contributes to providing information from the collected data(27) . It can predict traffic through traffic flow data (28). On the other hand, smart cities utilize big data due to the vast amount of data they collect (29). Multi-cloud computing provides a computational model that processes the huge amount of data. Smart automation is one of the most prominent modern technological applications in smart cities, which harnesses smart devices to serve the population. For instance, smartphone applications used in medical care can measure human vital signs such as heart rate, breathing, and oxygen levels, among others(24). Moreover, blockchain helps address security and privacy issues in digital transactions(30). Cybersecurity works to counter cyber-attacks, such as hacking attempts and other security threats that can exist in any digital environment (31).

3.3 Smart Sustainable Cities and addressing Climate Change

Smart cities use modern technology to respond to climate change and its environmental impacts. This technology contributes to improving the decision-making process and engaging citizens in providing effective solutions to address this phenomenon. Smart cities enhance resource management and improve the resilience of the urban environment. For example, smart city technology can improve waste management through sensors and data analysis, which helps reduce greenhouse gas emissions (2).

In addition, modern technology in smart cities contributes to dealing with climate change by changing citizens’ behavior, encouraging their participation as real actors in decision-making, and enhancing data transparency and accessibility. Digital technologies also contribute to extending the life of devices and reducing the carbon rate of energy consumed (32). Smart cities, on the other hand, address climate change challenges by emphasizing the need to move away from centralized energy management based on fossil fuels, and replace it with decentralized management based on renewable energy sources such as solar and wind energy(33).Therefore, smart cities address climate change by focusing on the level of greenhouse gas emissions, the use of sustainable renewable resources, and energy consumption rates (5).

Smart city planning that can deal with climate change consists of four main dimensions: Firstly, it involves enhancing resource management, conserving energy, cutting down on harmful emissions, and boosting afforestation. Second, climate change causes natural phenomena such as sea level rise, floods, droughts, hurricanes, and so on. Smart city technologies work to predict such phenomena and develop proactive plans for dealing with them. Furthermore, they prevent natural disasters and their consequences by establishing a cloud-based meteorological platform.

In the end, the importance of utilizing modern technologies to monitor climate change and provide data for developing adaptation strategies becomes clear (34). These technologies enable smart cities to adapt to climate challenges and mitigate their impacts. However, it is important to note that technical solutions alone are not sufficient to effectively address climate change; decisions must be made based on the data gathered from these technologies. Furthermore, many smart environmental solutions still need to be improved and implemented within the framework of urban policies to achieve the best outcomes (35).

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4. Discussion

Urban resilience refers to a city's ability to effectively manage challenges and disruptions. A resilient city is one that establishes flexible and adaptive relationships between its components and infrastructure, enhancing its capacity to cope with both natural and human-induced pressures. Sustainability is one of the key strategies that strengthens urban resilience, and when combined with modern technology, cities become more capable of providing a livable environment for their residents (4). In the context of sustainable smart cities, urban resilience is one of the most important concepts that has been explored in research. Zhou et al. (3) indicate that smart cities generally improve urban resilience through their economic role, as these cities push towards achieving the economic well-being of the population and providing suitable job opportunities. Through economic development, cities become better able to recover from urban changes and challenges, such as natural disasters.

Sustainable smart cities not only enhance urban resilience through economic aspects, but also focus on environmental and social aspects. Modern technologies enhance urban resilience and effectiveness by focusing on stability and regeneration processes. It seeks to achieve stability and rapid recovery, then develop the status quo to respond to any future events (36).

In the same context, Tarek & Ouf (37) confirm that smart, sustainable solutions improve cities' indicators of urban resilience”(A) Resources and materials availability, quality, and accessibility.(B)Communities’ safety, culture, and wellbeing.(C)Economic structure’s security, stability, and dynamism.(D) Built

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environment and infrastructure robustness and redundancy. (E) Institutions and governance planning mechanisms and its effectiveness of community organizations relationships”. However, decision-makers must be directed to harness technical solutions to enhance the ability of cities to deal with various changes and disturbances. Furthermore, focusing on meeting the population's social and economic needs, as well as improving the level of safety and health in the urban environment.

5. Conclusions

This study focused on contemporary trends in developing sustainable smart cities, aiming to integrate advanced technologies with urban infrastructure. The goal is to enhance the ability of small and medium-sized cities to adapt to climate change challenges and improve their resilience and urban efficiency. Through a review of relevant literature, the study demonstrated that adopting the sustainable smart city model, which involves integrating modern technologies into urban infrastructure, not only enhances cities' ability to manage the impacts of climate change but also strengthens their capacity to recover from natural and human-induced risks and absorb them without causing significant harm to the urban environment. As a result, sustainable smart cities are equipped with the resilience needed to adapt their urban environment to increasingly severe climate changes. However, there is a pressing need for more applied studies in this area, especially in small and medium-sized cities.

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