

Article

From a Traditional City to a Smart City: The Measurement of Cities' Readiness for Transition, Egypt as a Case Study

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Abstract: The transition from traditional legacy cities to smart cities represents a pivotal juncture in urban development and governance. As cities worldwide grapple with the challenges of rapid urbanization, resource constraints, and the need to enhance the quality of life for their citizens, the concept of a “smart city” has gained significant attention. This paper delves into the multifaceted process of urban transformation, shedding light on the essential criteria and considerations that guide a city’s conversion into a smart city. To provide a comprehensive framework for the conversion process, this paper outlines a computer program utilized to measure the readiness to transform a traditional city into a smart city. The transformation criteria encompass technological innovation, data-driven decision-making, infrastructure development, and effective governance models. It explores the significance of citizen engagement, privacy concerns, and sustainability in shaping the transformation process. Case studies of potential cities in Egypt that are ready to be successfully transformed into smart cities are presented to illustrate how these criteria have been applied in real-world contexts. Ultimately, this paper provides a roadmap for city planners, policymakers, and urban stakeholders, offering guidance on the essential elements and considerations required to navigate this complex and transformative journey successfully. In an era where urbanization continues to accelerate, the transition to smart cities is not merely a futuristic concept but a pressing necessity for ensuring the sustainability and prosperity of our cities.



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Keywords: traditional city; smart city; transformation; environment; economy; simulation; computer program

1. Introduction

According to the United Nations (UN), the world population reached 8.0 billion in 2022, which is more than three times that in 1950. The world population is projected to reach 8.5 billion in 2030 and to further increase to 9.7 billion in 2050 and 10.7 billion in 2100 [1]. In 1950, approximately 70% of the world population was residing in rural areas. The turning point occurred in 2007; for the first time in history, the global urban population exceeded the global rural population. In 2018, 55% of the world population (i.e., 4.2 billion) resided in urban areas. This percentage is expected to reach 60% in 2030. In 2050, more than two-thirds (68%) of the global population is projected to reside in urban areas, which is the reverse of that in the mid-twentieth century [2].

Due to the projected increased demand for urbanization [2], it is expected that the demand for smart cities and their applications and services will increase accordingly. According to Allied Market Research, the global smart cities market size was valued at \$648.4 billion and is expected to reach \$6.0 trillion in 2030, growing at a compound annual growth rate (CAGR) of 25.2% from 2021–2030 [3]. Consequently, the number of smart cities that contribute to enhancing the inhabitants' quality of life (QoL) will increase. According to a study produced by the Smart City Observatory, part of the IMD World

Competitiveness Center (WCC), the number of smart cities increased from 118 cities in 2021 to 141 cities in 2023 [4]. According to Statista, the global market of smart cities is expected to grow significantly, with approximately \$72.5 billion in 2024. This growth is anticipated to continue with a CAGR of 9.7% from 2024–2029. Accordingly, the market volume will reach \$113.5 billion by 2029 [5].

The US population is projected to continue urbanizing in the coming decades, with the urban share increasing and the rural share declining. As of 2023, about 80% of the US population lives in urban areas, while 20% live in rural areas. This represents a slight shift from 2010, when 80.7% of the population was urban and 19.3% was rural [6]. On the other hand, urbanization may face the following challenges: housing affordability, social inequality, and traffic congestion. To overcome the challenges, governments may make certain decisions; for example, governments need to invest in infrastructure and services to support urban growth, such as affordable housing, public transportation, and education. Policies are needed to address the challenges of urban inequality, such as poverty, crime, and social exclusion.

Egypt's urbanization is a complex phenomenon driven by multiple factors, making forecasting its future trajectory a daunting task. Despite the rapid economic growth in recent years, Egypt's urban population share remained relatively unchanged at around 43% in 2022 [7]. This deviates from the typical logistic trend of accelerating urbanization with economic development. Urbanization is heavily concentrated in major cities like Cairo, Alexandria, and Giza, leading to concerns about over-congestion and resource strain. Smaller cities and rural areas see slower growth, creating regional disparities. Job opportunities, higher incomes, and improved living standards in urban areas attract rural residents, fueling migration. Continued economic growth, coupled with investments in infrastructure and regional development, could influence future urbanization patterns. A growing population, combined with declining agricultural employment, is likely to push more people towards urban centers in search of better livelihoods. Government policies on urban development, infrastructure projects, and rural revitalization can significantly impact the pace and direction of urbanization. UN projections suggest a return to moderate urban population growth in the coming decades, reaching around 55% by 2050 [8]. This scenario emphasizes the need for balanced development and addressing regional disparities. Some experts warn of the possibility of faster urbanization, potentially exceeding 60% by 2050, driven by economic factors and population pressure [8]. This scenario raises concerns about managing megacities and ensuring sustainable urban development. Rapid urbanization can strain existing infrastructure and services, requiring significant investments in water, sanitation, transportation, and housing. Overcrowding, pollution, and informal settlements can pose social and environmental challenges. Sustainable urban planning and resource management are crucial. Urbanization can create new economic opportunities in sectors like construction, services, and manufacturing. Fostering innovation and entrepreneurship can be key. Overall, forecasting Egypt's urbanization requires a nuanced understanding of the interplay between economic, demographic, and policy factors. While challenges exist, the potential for sustainable and inclusive urban development is significant, requiring a proactive approach from policymakers and stakeholders.

This paper aims to measure the readiness of traditional cities to be transformed into smart cities with a case study of Egyptian cities. The criteria for selecting cities in this study are as follows: Firstly, major established cities, specifically provincial capitals, were chosen due to their significant service volume relative to their population size. Being provincial capitals means they encompass all the administrative services of their respective provinces. These cities require enhancement and efficiency improvements to transition into smart cities. The Egyptian government has expressed strong funding for this transition, which is evident from its initiatives like the Urban Development Fund and the "Decent Life Initiative" project. Secondly, this study also includes newer cities from the first, second, and third generations. The aim is to assess and elevate both old and new cities using the proposed model. To fulfill the research objectives, the initial step in our methodology

involves selecting cities for study. This selection hinges on specific foundational criteria for gauging their readiness for digital transformation.

1. The city should be one of the major existing cities, and the city should be the capital of the province.
2. The city should be one of the new existing cities.
3. The city should be in different conditions in terms of the culture of society and its needs, as the culture of the community varies according to the areas in which it lives, according to the customs, traditions, and living conditions available.
4. The clarity of the general format of the city and the clarity of the mutual relationship between its elements and planning units.
5. Availability of official information for each city that the proposed program needs to complete the program experience process in an optimal manner.

In this study, the methodology is structured to systematically measure the readiness of Egyptian cities for transitioning to smart cities, following a mixed-method approach. The methodology is designed to align directly with the research objectives and structure of the article. First, a framework based on the Smart City Maturity Model (SCMM) is used to assess readiness across key dimensions such as infrastructure, governance, and technology adoption. To gather empirical data, case studies of three Egyptian cities—Cairo, Alexandria, and New Administrative Capital—were conducted, with data collected from urban planning reports, governmental policy documents, and surveys administered to city officials and planners.

This empirical approach allows for a data-driven analysis of current infrastructure and governance structures in Egypt, providing a foundation for testing the research hypothesis. By incorporating both qualitative and quantitative data, the methodology enables a robust evaluation of the cities' readiness, ensuring that the results are not purely conceptual but grounded in real-world conditions. Furthermore, the data collected through this methodology informs the subsequent sections of the article, including the discussion of key challenges and recommendations for transitioning to smart cities.

2. Assessment Model Simulation [Methodology]

2.1. Hypothesis

Egyptian cities, while possessing foundational infrastructure, governance frameworks, and technological assets, are not fully equipped for a seamless transition to smart cities due to critical gaps in technology adoption, policy implementation, and urban governance. The readiness for this transition varies significantly across cities, with larger urban centers like Cairo and Alexandria being more prepared compared to smaller or less developed regions. The development of a tailored smart city readiness framework, specific to Egypt's socio-political and economic context, is essential to facilitate effective transitions.

2.2. Overview

- In this section, we highlight how the data collected from the empirical analysis support or contradict the theoretical assumptions outlined in the introduction. For instance, we discuss the implications of our findings on Egypt's readiness in terms of technological infrastructure, governance, and public engagement. This discussion helps contextualize the results within both the national and global smart city narratives and provides a clear understanding of the potential pathways for Egypt's cities to transition smoothly into smart city frameworks. This reorganization ensures a clear, logical progression of ideas, making the research easier to follow for the reader.
- The City Digital Transformation Readiness Assessment Model, as illustrated in Figure 1, is a tool designed to estimate the city's preparedness level. This tool streamlines city evaluations by offering selectable lists for assessment, as depicted in Table 1. Users can effortlessly make selections, and the system retains these choices. The researchers have developed and formulated a computer program using C++ to facilitate the measurement of cities' readiness for digital transformation. Through this program,

users can enter the name of a city or add a new city, input relevant information and data about the city, and initiate the evaluation process. As illustrated in Table 1, the program displays specific indicators for each component in the framework. Users can designate primary criteria and assign values (1–10 for achieved, 0 for not achieved) to secondary indicators. The program records these values and computes the city's readiness for digital transformation, presenting the overall percentage. Once evaluations are complete, the tool compiles all findings, presenting them in an Excel format that can be printed and utilized for informed decision-making.

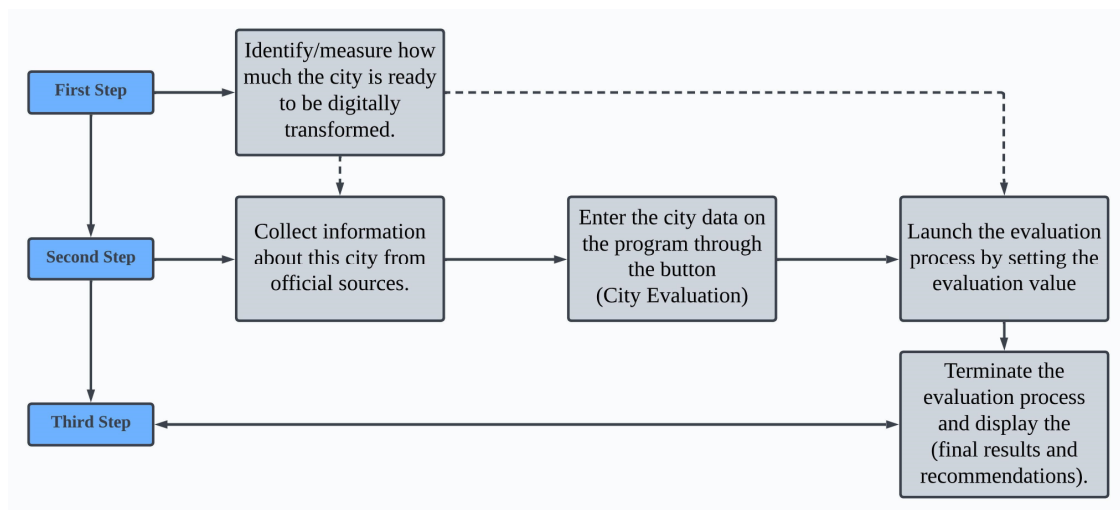


Figure 1. Computer program diagram.

Table 1. Selected lists for assessment.

	Extremely Agree	Strongly Agree	Neutral	Strongly Disagree	Extremely Disagree
The existence of training centers in the city's agencies and institutions to train employees and workers on the digital transformation process.					
Enacting laws and requirements that grant priority in job placement to individuals who complete certain city-mandated courses.					
Changing legacy concepts by accepting the process of technological change.					
Active participation and giving the right to accept or reject decisions.					
Continuous participation in the process to achieve the users' aspirations for the better and actual involvement in the transformation of their city.					
Improving the services provided to citizens, as well as their quality of life (QoL) and other important daily life issues for inhabitants.					
Providing private electronic or virtual places for individuals or groups to meet					
Governance Standards					
Data availability, security, and seamless data processing through e-government portals, whether with citizens, official employees, or businessmen who have common interests with the government through IoT applications in the governance of all city services.					

Table 1. Cont.

	Extremely Agree	Strongly Agree	Neutral	Strongly Disagree	Extremely Disagree
Seamless and transparent involvement in decision making through various platforms to maximize the participation.					
Expressing an opinion on the entire city's digital services and e-platforms to facilitate making the correct decision and unifying the spirit of cooperation between service providers and recipients.					
The existence of the electronic voting system allows the inhabitants to vote on the decisions offered for community discussion and obtain the opinion of the citizens with full transparency. The voting results are given to the officials to clarify the extent of their satisfaction or dissatisfaction with the performance of the city.					
Telecommunications Infrastructure Standards					
Availability of facilities for training, creativity, new applications, and various innovations.					
Continuous availability of technical support for all digital services and applications, ensuring no interruptions or malfunctions.					
Provision of digital platforms for all city institutions and the private sector, along with support for existing platforms used to offer or access services.					
Availability of infrastructure and knowledge of inactive network paths to ensure uninterrupted full-time support.					
Availability of alternative routes in case of interruptions or malfunctions in active cables or other telecommunication network infrastructure to make sure the fully functional networks.					
Provision of comprehensive data protection for citizens to ensure security and transparency during transactions with their data across all agencies, banks, and city services.					
Smart Transportation Standard					
The availability of cables, optical fibers, signals, and surveillance cameras, as well as information and data, for seamless traffic monitoring and management.					
The availability of a control and operations center to monitor traffic, manage violators, and track road weather conditions.					
Provision of parking spaces throughout the city, accessible via mobile phone or tablet applications, allowing users to identify and locate the nearest available parking spot for their vehicle.					
The availability of public transportation buses and their interconnected routes throughout the city enables comprehensive coverage of transportation services. This includes booking seats and accessing onboard services during trips across multiple stations towards destinations. These services are facilitated through electronic apps on smartphones, providing users with real-time bus/train arrival times, pre-trip, during-trip, and post-trip information, as well as an integrated electronic payment system.					
The availability of an electronic payment system through electronic stickers or transponders allows drivers to access parking lots and pass through electronic gates on highways, bridges, and tunnels. Using electronic toll collection enables seamless and automatic payment of tolls and fines, aiding the transportation sector in efficiently collecting fees and promptly developing its facilities.					
The presence of devices and sensors enables emergency services and first responders to pinpoint the location of a vehicle and identify the source of its malfunction, allowing them to make appropriate and timely decisions.					
The presence of cables, optical fibers, signals, and surveillance cameras, along with access to information and data, ensures seamless traffic monitoring and management.					

Table 1. Cont.

	Extremely Agree	Strongly Agree	Neutral	Strongly Disagree	Extremely Disagree
Smart Energy Standard					
The presence of power plants, whether medium or low voltage, along with monitoring systems and an electronic control system for the city's distribution network, ensures seamless, necessary, and prompt switching on/off the network, facilitating development and quick decision-making.					
Establishing essential infrastructure to connect and install smart meters in compliance with requirements and controls for establishing, operating, securing, monitoring, and controlling infrastructure systems.					
Transitioning traditional meters to smart meters across all city buildings and authorities involves specifying installation locations and detailing the connection process to the telecommunications network and smart services through licensed service providers.					
Establishing the necessary infrastructure for electric vehicle charging stations in various locations such as homes, commercial places like malls, educational institutions, and governmental facilities.					
Transforming traditional lighting poles into smart poles powered by renewable solar energy. These smart poles will incorporate various functions such as lighting, mobile phone charging, display screens, and surveillance cameras for urban areas. They will also feature seating areas and can be controlled through smart applications.					
Urbanization Standards					
The availability of diverse housing options including apartments of varying sizes, alongside the conversion of existing buildings into sustainable smart buildings. These smart buildings will integrate control of all devices and sensors through mobile applications. Implementing smart building technologies will streamline energy management for utilities such as water, electricity, and waste, ensuring the highest quality standards for residents in a smart city environment.					
Assessing the convenience of roundtrip transportation both within and between city areas using a variety of public transportation options. Evaluating road efficiency across different levels and capacities to enhance resident comfort within the city.					
Measuring the distribution of services within the city relative to factors such as total area, population, and various service sectors including commercial, health, educational, recreational, and industrial services.					
Economic Standards					
The presence of a digital financial infrastructure supporting electronic transactions enables the city to meet citizen needs for e-commerce, banking services, and financial transactions through electronic applications. This infrastructure prioritizes maintaining the security and confidentiality of citizen and economic institution data, emphasizing cybersecurity measures.					
Improving the average annual income per capita in the city.					
Addressing unemployment rates and inadequate job opportunities within society.					
Ensuring the availability of suitable employment opportunities tailored to individuals' specialties within society, whether in-person or remote.					
Environmental Standard					
Implementing waste collection services for residential, commercial, industrial, and economic institutions—including factories and companies—via electronic applications designed to manage waste effectively.					
Assessing the effectiveness of city resource management and strategies to conserve them through awareness of resource utilization from production to utilization, preservation, and sustainable development.					

Table 1. Cont.

	Extremely Agree	Strongly Agree	Neutral	Strongly Disagree	Extremely Disagree
Assessing the city’s capacity to ensure clean water and air for residents, free from pollution and emissions, using sensors to monitor parameters such as water and air quality, fog conditions, visibility density, and harmful atmospheric emissions.					
Social Standards					
Creating virtual spaces to facilitate social activities that enhance community integration among groups, such as hosting residential building community meetings or family gatherings on digital or social platforms.					
Ensuring the availability of comprehensive security services to safeguard residents, encompassing both physical security measures like surveillance cameras and cyber security protocols. This includes protecting citizens’ data to ensure safe and secure online activities without risk of threats or breaches.					
Delivering education services across all levels (pre-college, undergraduate, and graduate) through diverse formats such as distance education, hybrid models, and traditional in-person classes. This is facilitated by offering various digital platforms to support educational institutions.					
The goal is to offer medical services to citizens by creating digital patient files. Each file will contain the latest diagnosis, medical history, prescriptions, radiology files, and other essential data to understand the patient. Additionally, these cases can be submitted to multiple doctors across different locations for second opinions.					

To establish the simulation for the proposed program, a clear formulation of a set of objectives must be developed as follows:

1. Facilitating the city evaluation process utilizing lists of cities, which can be used to select the cities under examination seamlessly.
2. Retaining the information/results in a way that enables the researcher to access it at any time.
3. Coordinating the procedure of evaluating the performance of cities and arranging the results.
4. Promoting the digital transformation process using computer applications, making it more accurate and transparent.

The methodology of the application depends on a set of steps as follows:

1. Identify/measure how much the city is ready to be digitally transformed.
2. Collect the city information from official sources. Then, input the collected data into the program through the button (City Evaluation). Finally, launch the evaluation process by setting the evaluation value, which equals 10 points for each indicator if it is fulfilled, and 0 otherwise.
3. Click on the (Analysis and Recommendations) button to terminate the evaluation process and show the final results and recommendations.

2.3. The Prior Studies

Case studies offer valuable insights into the practical application of smart city concepts and frameworks. El-Masri [9] et al. investigated the impact of innovative technologies on the transformation of smart cities in Egypt. Their findings suggest that while there is significant potential for smart city development in the country, challenges such as data governance, resource allocation, and public engagement need to be addressed to realize this potential.

Salem et al. provided [10] an overview of smart city initiatives in Egypt, highlighting the strategies and challenges associated with these efforts. They noted that while new cities such as New Cairo and New Assiut are being developed with smart city principles in mind, established cities like Alexandria are also undergoing transformations to enhance their digital infrastructure and service delivery.

The case of Alexandria, as explored by Arafa and Aziz [11], illustrates the complexities of smart city transformation in a large, established urban environment. The city's efforts to implement the "New General Strategic Plan for the City of Alexandria 2032" reflect a broader trend of integrating smart technologies with traditional urban planning practices to create more resilient and sustainable cities.

2.4. The Research Methodology

The research deals with measuring the readiness of cities for digital transformation by applying scientific methods by monitoring standards, measuring the readiness of cities, and deducing a theoretical model through which the applied model can be deduced to be able to evaluate to support decision-makers in choosing cities that are capable of digital transformation or not. To achieve this, a methodology has been prepared through which the hypothesis of the research can be verified and achieved through the three stages:

- The First Stage: In this stage, we identify the basic concepts of the research axes (the information revolution and its development, information technology and its development, as well as the impact of communications and information technology on the city's urbanization—digital transformation and its impact on the sustainability of the city—the impact of monitoring digitalization on the smart governance of urban management of the city) where the relationship between these three axes is studied. Digital transformation is studied as an input to assess the readiness of cities and the impact of this digital transformation and its relationship to the concept and standards of sustainability, linking literary references to the dimensions of digital transformation, monitoring digital transformation standards, and preparing a list of different standards for preparing a measurement ruler.
- The Second Stage: This stage focuses on the deductive analytical approach through the preparation of an analytical study that focuses on how to convert these standards into numerical semantics through the work of a questionnaire, through which we will obtain the degree of importance of each criterion "rank" or "relative importance", and from each rank, the "relative weight" of each criterion is calculated, and these standards come through (reference, global and local standards/codes, and standards concluded according to previous studies). Theoretical and analytical studies [12] relied on the digital transformation of the city to reach the research to:
 - Prepare a measurement procedure for digital transformation standards to measure the readiness of cities through (reference standards—international standards—inferential standards).
 - Prepare a theoretical model to evaluate these standards through a questionnaire for specialists in the field of architecture and planning, using one of the measurement methods to confirm the standards of this approach, and set a degree of importance for each criterion.
- The Third Stage: The study is applied by converting this theoretical model into an applied model to measure the readiness of cities that is applied to cities' "study cases", and this requires studying the reasons and criteria for selecting the cities under study, identifying them, and formulating the proposed curriculum in the form of a computer program that can be used to measure the readiness of cities for digital transformation with an explanation of how to use the program and apply it to the cities under study, then presenting the results and recommendations of the research.

2.5. Launch the Assessment Model

1. The First Step: Select the city to be measured and enter its data, including the choices.
 - Add/modify the name of the city.
 - Add/modify the name of the province.
 - Choose the nature of the city, specifying if it is “urban or rural”.
 - Add/modify the year of construction.
 - The population of the city.
2. The Second Step: Select criteria and indicators and enter their data and values.
 - Add the name of the main standard from the list.
 - Add indicators belonging to the main standard from the list.
3. The Third Step: Choose the evaluation list and measure and save data for the city through the following:
 - Open the evaluation list and confirm the choice of the city to be evaluated and measured from the list of cities from the city selection button.
 - Choose the main standard from the list.
 - Then, choose the indicators of the standard from the list attached to the relative weight.
 - Then, have the specialist evaluate the indicators (if any) in the city from [1–10], and if they are not present, have them put the number [0].
 - Repeat the evaluation for each main standard and its indicators.
 - After completing the evaluation mode, click on the (Save) button to save the data for that city in the program for the possibility of referring to it if it is needed for that city.
4. The Fourth Step: Analyze data and extract outputs and results as follows.

Upon concluding the city evaluation and storing the selected data, users can proceed to the fourth option labeled “Analysis and Recommendations”. In this step, the program assesses the city by assigning a relative score (represented as a percentage). This score indicates the city’s readiness for digital transformation as of the evaluation date, which is prominently displayed at the top of the app window. The tool not only generates this score but also extracts all relevant recommendations. Users can export this comprehensive data using the designated button, allowing for seamless utilization by decision-makers and administrative authorities in the city.

3. Background

3.1. Traditional City

Traditional cities refer to urban areas that have developed over time through organic growth, historical evolution, cultural influences, and societal practices, often characterized by distinct architectural styles, spatial layouts, cultural heritage, social structures, and community identities, as illustrated in Figure 2 [13,14]. These cities are typically complex, multifaceted, and dynamic urban entities that embody historical, cultural, architectural, social, economic, and spatial dimensions shaped by centuries of human settlement, interaction, innovation, adaptation, and evolution [15]. While these cities face various challenges related to modernization, urbanization, preservation, sustainability, governance, and livability, they continue to inspire, fascinate, and resonate with people around the world due to their enduring charm, authenticity, character, heritage, and sense of place.

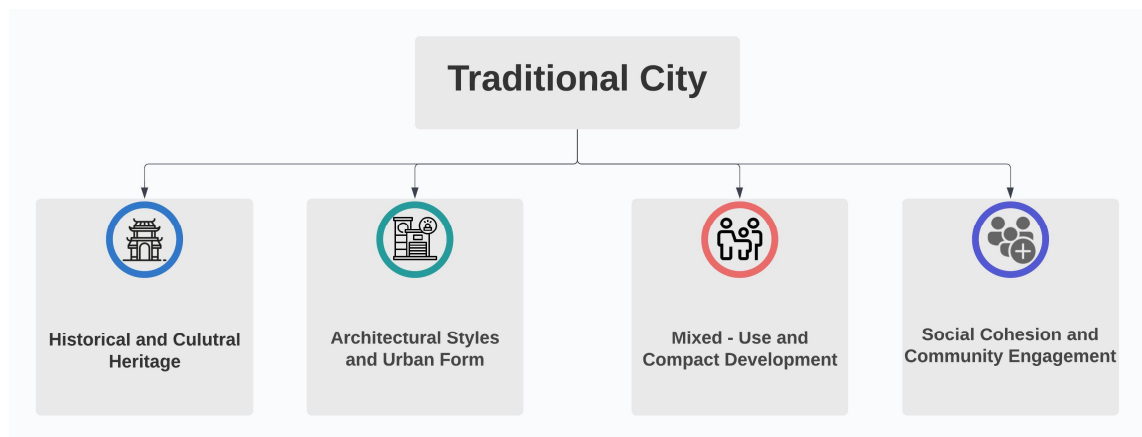


Figure 2. Traditional city model.

3.1.1. Historical and Cultural Heritage

Traditional cities often contain significant cultural and historical landmarks, such as temples, mosques, churches, palaces, and historical sites. These landmarks contribute to the city's identity and are often preserved or protected to maintain the city's heritage. The cultural and historical significance of traditional cities encompasses a wide range of tangible and intangible elements that contribute to their unique identity, character, and sense of place [16]. These cities serve as living embodiments of cultural heritage, traditions, values, and practices that enrich the lives of residents and visitors alike while preserving and celebrating the collective memory of past generations.

- **Architectural Heritage:** Traditional cities are often characterized by architectural styles and techniques that have evolved over centuries, reflecting the influences of various civilizations, religions, and cultural traditions. Examples include the medieval cathedrals in European cities, the Islamic palaces and mosques in Middle Eastern cities, and the traditional courtyard houses in Chinese cities [17].
- **Historical Landmarks:** These cities typically contain significant historical landmarks such as temples, palaces, forts, city walls, and archaeological sites that serve as tangible links to the past. These landmarks often have cultural, religious, or political significance and contribute to the city's identity and sense of place [18].
- **Urban Fabric and Layout:** The urban fabric and layout of traditional cities often reflect historical and cultural influences, including religious beliefs, social hierarchies, and economic systems. Examples include the gridiron pattern of ancient Roman cities, the organic growth of medieval European cities, and the Islamic city layout centered around a mosque and bazaar [19].
- **Cultural Institutions and Practices:** Historical cities are often home to cultural institutions such as museums, theaters, libraries, and religious institutions that preserve, celebrate, and promote local traditions, arts, crafts, music, dance, literature, and cuisine. These institutions play a vital role in maintaining cultural continuity and fostering community identity [20].
- **Festivals and Celebrations:** Such cities frequently host festivals, celebrations, and religious ceremonies that showcase local traditions, customs, rituals, and folklore. These events often involve community participation, public gatherings, parades, performances, and culinary delights, reinforcing cultural identity and social cohesion [21].
- **Sacred and Ritual Spaces:** Many traditional cities contain sacred and ritual spaces such as temples, mosques, churches, shrines, and pilgrimage sites that are central to religious beliefs, practices, and ceremonies. These spaces often have architectural and symbolic significance and serve as spiritual landmarks within the cityscape [22].
- **Social Practices and Customs:** Traditional cities maintain social practices, customs, norms, and values that govern interpersonal relationships, community interactions, family structures, gender roles, and rites of passage. These practices often reflect

cultural heritage, religious beliefs, ethical principles, and societal norms that shape daily life and community dynamics [23].

3.1.2. Architectural Styles and Urban Form

Traditional cities are often characterized by distinctive architectural styles, urban forms, spatial layouts, and design elements that reflect the influences of various civilizations, religions, cultures, and historical periods. Examples include medieval European cities with narrow streets, historic mosques, churches, temples, palaces, courtyards, squares, bazaars, and traditional vernacular architecture.

- **Architectural Style:** The architecture in traditional cities often reflects the local culture, climate, and available materials. Buildings might feature traditional construction methods, local materials, and design elements that have been passed down through generations. Examples include courtyards in Mediterranean cities, wooden structures in East Asian cities, and adobe buildings in desert regions. Architecture in traditional cities reflects a blend of cultural, historical, environmental, and functional considerations [24]. It reflects the values, beliefs, and lifestyles of the societies that created it, while also responding to the practical challenges of urban living.
- **Materials and Construction Techniques:** The choice of building materials and construction techniques is often influenced by local resources and climate. For instance, regions with abundant timber might have predominantly wooden architecture, while areas with readily available stone or mudbrick would use these materials extensively [25].
- **Cultural and Religious Symbols:** Traditional architecture often incorporates symbols and motifs that reflect the culture, religion, and values of the society. For example, Hindu temples in India feature intricate carvings of deities and mythological scenes, while Islamic architecture includes geometric patterns and calligraphy [26].
- **Functional Design:** Traditional cities often feature buildings designed to meet specific functional needs, such as protection from the elements, natural ventilation, and communal living. Examples include courtyard houses in the Middle East, which provide privacy and shade, and stilt houses in Southeast Asia, which offer protection from floods and wildlife [27].
- **Public Spaces and Landmarks:** Historical cities typically have well-defined public spaces, such as squares, markets, and religious sites, which serve as focal points for social interaction and community activities. Landmarks like palaces, temples, and forts often dominate the cityscape, reflecting the political and religious importance of these institutions [28].
- **Adaptation to Climate:** Traditional architecture is often adapted to local climatic conditions, with features like thick walls for insulation, high ceilings for ventilation, and overhanging roofs for shade. For example, traditional buildings in desert regions may have thick walls and small windows to keep interiors cool, while those in colder climates might feature south-facing windows for passive solar heating [29].
- **Art and Decoration:** Historical architecture often incorporates decorative elements such as carvings, paintings, and textiles, which serve both aesthetic and symbolic purposes. These decorative elements can be found on facades, interiors, and religious structures, enhancing the visual appeal and cultural significance of the buildings [30].

3.1.3. Mixed-Use and Compact Development

Traditional cities typically feature mixed-use, compact, and walkable urban environments where residential, commercial, cultural, recreational, and social activities coexist in proximity, fostering pedestrian-friendly neighborhoods, vibrant street life, and community interactions. Due to their historical development, many traditional cities were designed for pedestrian movement. Narrow streets, pedestrian alleys, and pathways encourage walking and create a sense of intimacy and connection among residents. A pedestrian-friendly traditional city is designed with human-scale principles that prioritize walking, cycling, and public transportation over automobile traffic. Such cities are characterized by their

compact urban form, well-connected street networks, mixed land uses, and vibrant public spaces [31].

- **Compact Urban Form:** Pedestrian-friendly cities typically have a compact, dense urban form that minimizes the need for long-distance travel by car. This allows residents to access essential services, amenities, and public spaces within walking or cycling distance [32].
- **Mixed Land Uses:** Traditional cities often feature mixed-use development, where residential, commercial, recreational, and institutional activities are integrated within the same neighborhood or district. This creates a diverse range of destinations and amenities that are easily accessible on foot or by bicycle [33].
- **Well-Connected Street Networks:** Pedestrian-friendly cities have well-connected street networks with a gridiron or hierarchical layout that facilitates easy navigation and movement. This includes wide sidewalks, pedestrian-friendly crossings, and traffic-calmed streets that prioritize the safety and convenience of pedestrians and cyclists [34].
- **Vibrant Public Spaces:** Traditional cities often have vibrant public spaces such as plazas, squares, parks, and promenades that serve as gathering places for social, cultural, and recreational activities. These spaces are designed to accommodate pedestrians and cyclists, with amenities such as seating, shade, public art, and pedestrian-friendly infrastructure [35].
- **Public Transportation:** Pedestrian-friendly cities prioritize public transportation systems such as buses, trams, and metros to reduce reliance on private cars. Transit hubs, stations, and stops are strategically located within walking distance of residential and commercial areas, making it easy for residents and visitors to use public transport [36].
- **Traffic-Calming Measures:** Historical cities employ various traffic calming measures such as speed limits, traffic circles, chicanes, and pedestrian zones to reduce vehicle speeds, improve safety, and create a more walkable and livable environment [37].
- **Accessibility and Inclusivity:** Pedestrian-friendly cities prioritize accessibility and inclusivity by providing barrier-free environments, accessible infrastructure, and amenities for people of all ages, abilities, and backgrounds. This includes pedestrian ramps, tactile paving, audible signals, and other features that accommodate diverse needs [38].

3.1.4. Social Cohesion and Community Engagement

Traditional cities often have strong social cohesion, community ties, interpersonal relationships, and collective identities among residents, fostering a sense of belonging, mutual support, cultural continuity, and shared values within diverse communities.

- **Social Interaction:** The design and layout of traditional cities promote social interaction among residents. Shared public spaces, community events, and close-knit neighborhoods foster a sense of community and belonging. Social interaction in traditional cities is a multifaceted phenomenon shaped by urban fabric, cultural norms, religious beliefs, economic activities, historical context, etc. [39]. These cities provide a rich and diverse social environment that fosters interpersonal relationships, community engagement, cultural expression, and collective identity among residents [40].
- **Community Cohesion:** Traditional cities typically have close-knit communities characterized by strong social bonds, mutual support networks, and collective identity. Residents often know their neighbors, participate in community events, and engage in communal activities that foster a sense of belonging and solidarity [41].
- **Family and Kinship Networks:** Family and kinship networks are integral to social interaction in traditional cities, providing emotional support, economic assistance, and social connections across generations. Extended families often live in close proximity, share resources, and participate in family gatherings, celebrations, and rituals that reinforce familial bonds [42].

- **Economic Activities:** Traditional cities often have localized economies characterized by artisanal production, small-scale commerce, and informal markets that facilitate social interaction among producers, traders, consumers, and artisans. Markets, workshops, and commercial districts serve as places where people exchange goods, services, information, and social capital [43].
- **Social Norms and Etiquette:** Such cities have established social norms, etiquette, and codes of conduct that govern interpersonal relationships, communication, behavior, and social interaction. Respect for elders, hospitality, reciprocity, and community solidarity are often emphasized, fostering harmonious coexistence and social cohesion [44].
- **Public Events and Gatherings:** Public events, gatherings, markets, fairs, and festivals are common in traditional cities, providing opportunities for social interaction, entertainment, and community engagement. These events often attract people from diverse backgrounds, fostering cultural exchange, social integration, and mutual understanding [45].

3.1.5. Challenges and Preservation

While traditional cities have unique charm and historical significance, they also face challenges such as population growth, infrastructure demands, and modernization pressures. Balancing preservation efforts with the need for development and infrastructure improvements is a common challenge for these cities. Indeed, traditional cities face a myriad of challenges as they grapple with the pressures of population growth, urbanization, infrastructure demands, economic development, and modernization. Balancing preservation efforts with the need for sustainable growth and infrastructure improvements is a complex and multifaceted issue that requires careful planning, collaboration, and innovative solutions [46]. In summary, balancing preservation efforts with the need for development and infrastructure improvements in traditional cities requires a holistic, integrated, and sustainable approach that considers economic, social, cultural, environmental, and governance dimensions. Collaborative planning, stakeholder engagement, innovative solutions, and adaptive management strategies can help traditional cities navigate these challenges while preserving their unique charm, historical significance, and cultural heritage for future generations [47]. The common challenges for traditional cities are as follows:

- **Population Growth and Density:** As traditional cities experience population growth, they often face challenges related to housing shortages, overcrowding, traffic congestion, and increased demand for public services. Managing urban density, improving housing affordability, and enhancing transportation networks are critical issues that require careful planning and sustainable urban development strategies [48].
- **Infrastructure Upgrades:** Traditional cities often have aging infrastructure that requires upgrades, maintenance, and modernization to meet current and future needs. Balancing preservation efforts with the need for infrastructure improvements such as roads, bridges, public transit, utilities, and public spaces is essential to ensure the safety, functionality, and resilience of the city's built environment [49].
- **Economic Development:** Such cities often face pressures to modernize and diversify their economies to remain competitive in the global marketplace. Encouraging sustainable economic growth, supporting local businesses, promoting tourism, and attracting investment while preserving the city's unique character and cultural heritage is a complex challenge that requires strategic planning and stakeholder engagement [50].
- **Environmental Sustainability:** Historical cities must also address environmental sustainability challenges such as pollution, resource depletion, climate change, and natural hazards. Implementing green infrastructure, sustainable transportation systems, energy-efficient technologies, and resilience measures can help mitigate environmental impacts and enhance the city's long-term sustainability [51].

- Governance and Planning: Effective governance, urban planning, and regulatory frameworks are essential to address the complex challenges facing traditional cities. Collaborative decision-making, multi-stakeholder engagement, long-term planning, and adaptive management strategies can help ensure that development and preservation efforts are aligned with the city's goals, values, and priorities [52].

3.1.6. Examples of Traditional Cities

- Europe:
 1. Prague, Czech Republic [53].
 2. Cinque Terre, Italy [54].
 3. Sintra, Portugal [55].
 4. Barcelona, Spain [56].
- Asia:
 1. Hoi An, Vietnam [57].
 2. Ubud, Bali [58].
 3. Jaipur, India [59].
 4. Kyoto, Japan [60].
- Latin America:
 1. Oaxaca, Mexico [61].
 2. Valparaíso, Chile [62].
 3. Bariloche, Argentina [63].

3.2. Smart City

A smart city is an urban area that uses digital technologies, data analytics, and Internet of Things (IoT) sensors to enhance the quality of life for its residents, improve infrastructure efficiency, foster economic growth, and promote sustainable development. The concept of a smart city encompasses various aspects, including governance, mobility, environment, economy, and quality of life [64]. In summary, a smart city is a holistic, integrated, and sustainable urban ecosystem that leverages technology, data, innovation, and collaboration to address complex urban challenges, improve quality of life, enhance economic competitiveness, and promote environmental sustainability. While the concept of a smart city offers numerous benefits and opportunities, it also presents challenges related to privacy, cybersecurity, equity, governance, scalability, and implementation that require careful consideration, planning, and management [65]. As depicted in Figure 3 [64], the essential characteristics of smart cities include the following components:

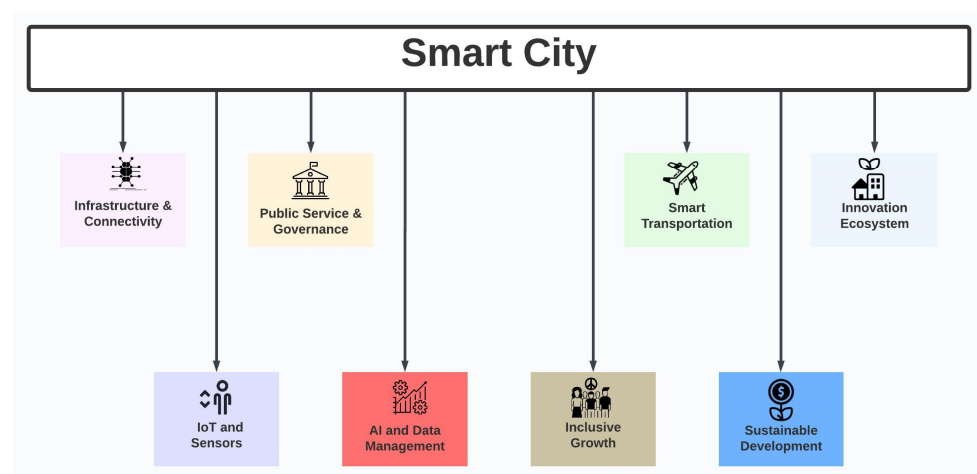


Figure 3. Smart city model.

3.2.1. Infrastructure and Connectivity

Smart city infrastructure and connectivity refer to the technological backbone and networks that enable cities to collect, analyze, and utilize data for improving the quality of life, efficiency of services, and sustainability [66]. In essence, smart city infrastructure and connectivity lay the groundwork for integrating technology into urban environments, fostering innovation, efficiency, and sustainable growth. Here is a breakdown:

- Infrastructure:

1. Digital Infrastructure: This encompasses the hardware, software, and platforms that support the smart city ecosystem. This includes sensors, IoT devices, data centers, and cloud computing resources [64,67].
2. Physical Infrastructure: Roads, bridges, public transport systems, energy grids, and buildings can be integrated with smart technologies. For instance, smart grids allow for efficient energy distribution, while intelligent transportation systems optimize traffic flow [68].

- Connectivity:

1. High-Speed Internet: A foundational element for any smart city is high-speed, reliable internet connectivity. This facilitates real-time data transmission and supports various smart applications [66].
2. IoT Connectivity: Internet of Things (IoT) devices, such as sensors and actuators, require connectivity to transmit data. Cellular technologies like 5G are crucial for supporting a vast number of connected devices with minimal latency [64,69–71].
3. Interoperability: For a truly connected smart city, different systems and devices must be able to communicate and share data seamlessly. Standards and protocols ensure that diverse technologies can work together cohesively [72].
4. Cybersecurity: With increased connectivity comes the challenge of securing vast amounts of data and systems from cyber threats. Robust cybersecurity measures are essential to protect sensitive information and infrastructure [73].

3.2.2. IoT and Sensors

IoT refers to the interconnectedness of devices and systems embedded with sensors, software, and other technologies to collect and exchange data across various smart city sectors, including transportation, energy, healthcare, public safety, and waste management [74]. These sensors collect real-time data on traffic patterns, air quality, energy consumption, water usage, waste generation, and other key indicators, enabling informed decision-making and resource optimization. Smart city IoT and sensors enable cities to improve operational efficiency, enhance sustainability, and create more livable urban environments by integrating technology into various facets of city management and infrastructure [75].

- Applications:

1. Smart Transportation: IoT-enabled traffic management systems can optimize traffic flow, reduce congestion, and improve public transportation efficiency. This includes smart parking systems, real-time traffic monitoring, and intelligent public transit solutions [76].
2. Waste Management: Waste management is a critical aspect of smart city infrastructure, focusing on the efficient collection, transportation, processing, recycling, and disposal of waste. Smart waste management systems leverage technology to optimize these processes, reduce environmental impact, and improve urban living conditions. Smart waste bins equipped with sensors can signal when they are full, optimizing collection routes and schedules [77].
3. Public Safety: Public safety in smart cities encompasses various aspects, including crime prevention, emergency response, and disaster management. By leveraging advanced technologies, cities can enhance their public safety infrastructure, ensuring a safer environment for residents and visitors. IoT devices like surveillance cam-

eras, gunshot detectors, and emergency response systems enhance urban safety by providing real-time monitoring and alerts [78].

4. **Environmental Monitoring:** Environmental monitoring in smart cities involves the use of advanced technologies to track and manage environmental conditions. This helps in maintaining a healthy urban environment, promoting sustainability, and ensuring public health. Sensors can monitor air quality, noise levels, water quality, and other environmental factors to inform city planning and improve public health [79].
5. **Energy Management:** Energy management in smart cities involves the use of advanced technologies and strategies to optimize the generation, distribution, and consumption of energy. This approach aims to enhance energy efficiency, reduce costs, and minimize environmental impact. Smart grids and meters enable efficient energy distribution, consumption monitoring, and integration of renewable energy sources [74,75].

■ **Sensors in Smart Cities:**

1. **Environmental Sensors:** Environmental sensors are critical components in smart cities, providing real-time data on various environmental parameters, for instance, measuring parameters like air quality, temperature, humidity, and pollution levels. These data help city planners, policymakers, and citizens make informed decisions to improve urban living conditions, ensure public health, and promote sustainability [79].
2. **Traffic Sensors:** Traffic sensors are a key component of urban infrastructure designed to improve traffic management by monitoring traffic flow and vehicle counts, detecting/reducing incidents and congestion, and enhancing overall city mobility. These sensors collect data on various aspects of traffic flow and environmental conditions, which can then be analyzed to inform decisions and optimize transportation systems [80]. Smart city traffic sensors are crucial for creating more efficient, safe, and sustainable urban environments. By leveraging advanced technologies and data analytics, cities can significantly enhance the quality of life for their residents and visitors.
3. **Noise Sensors:** Also known as acoustic sensors, these are devices used to measure sound levels in various environments. In the context of smart cities, these sensors play a vital role in monitoring and managing urban noise pollution, which is crucial for improving the quality of life and ensuring compliance with environmental regulations [81]. By leveraging advanced sensor technologies and data analytics, city authorities can effectively monitor, manage, and mitigate noise pollution.
4. **Water Sensors:** These are critical components in smart city infrastructure, designed to monitor various aspects of water quality, availability, including water levels in reservoirs, and distribution. These sensors play a significant role in ensuring the sustainable management of water resources, detecting leaks, and maintaining public health and safety [82]. Water sensors are crucial for the effective and sustainable management of water resources in smart cities. By providing real-time data and insights, these sensors help city authorities make informed decisions, improve water quality, and ensure the efficient use of this vital resource.
5. **Functionality Sensors:** These collect real-time data from the urban environment, which is then analyzed to derive insights, optimize city operations, and enhance the quality of life for residents [83].
6. **Integration with IoT:** Sensors are integral components of IoT systems. They gather data from the physical environment, which is transmitted, processed, and acted upon through interconnected IoT devices and platforms [84].

3.2.3. Data Analytics and Artificial Intelligence (AI)

Smart cities use data analytics, machine learning, and AI algorithms to analyze vast amounts of data collected from sensors, social media, and other sources within the city. These technologies provide insights into urban trends, patterns, and anomalies, enabling predictive modeling, optimization of services, and proactive management of city resources. AI refers to the simulation of human intelligence processes by machines, including learning, reasoning, problem-solving, and decision-making. Smart city data analytics and AI

technologies empower cities to transform vast amounts of data into actionable insights, automate processes, improve service delivery, and create more resilient, sustainable, and livable urban environments for residents [85].

- Data Analysis:

1. Urban Planning: Analyzing demographic data, traffic patterns, and infrastructure utilization helps urban planners make data-driven decisions about city development, zoning, and infrastructure investments [86].
2. Public Safety: Analyzing crime data, emergency response times, and incident reports enables law enforcement agencies to allocate resources effectively and proactively address safety concerns [78,87].
3. Infrastructure Management: Monitoring and analyzing data from public utilities, transportation systems, and waste management services facilitates efficient maintenance, repairs, and upgrades [64,67].
4. Environmental Sustainability: Analyzing environmental data such as air quality, waste generation, and energy consumption helps cities implement sustainable practices and reduce their environmental footprint [88].

- Artificial Intelligence (AI) in Smart Cities:

1. Traffic Management: Traffic management systems are crucial for creating efficient, safe, and sustainable urban transportation networks. By leveraging advanced technologies, cities can enhance traffic flow, reduce congestion, improve road safety, and contribute to a better quality of life for their residents. AI-powered systems analyze real-time traffic data to optimize signal timings, manage congestion, and improve traffic flow [80].
2. Predictive Maintenance: Predictive maintenance is an advanced approach to maintaining equipment and infrastructure by predicting when maintenance should be performed to prevent unexpected failures and extend the lifespan of assets. It relies on data analytics, machine learning, and IoT technologies to monitor the condition of equipment in real time and forecast potential issues before they occur. AI algorithms analyze data from city infrastructure to predict equipment failures, optimize maintenance schedules, and reduce downtime [89,90].
3. Energy Efficiency: AI-driven smart grids and energy management systems optimize energy distribution and consumption patterns and integrate renewable energy sources to enhance efficiency and sustainability [75,91].
4. Public Services: AI-powered chatbots, virtual assistants, and automated customer service systems enhance the efficiency and responsiveness of public services, such as utilities, transportation, and municipal services [92].
5. Emergency Response: AI algorithms analyze data from various sources, including sensors, social media, and public records, to predict and respond to emergencies more effectively, allocate resources efficiently, and mitigate risks [93].

3.2.4. Sustainable Development

Smart city sustainable development refers to the strategic and holistic approach cities adopt to achieve economic prosperity, social inclusivity, and environmental sustainability while addressing the challenges of rapid urbanization and resource constraints. Smart cities prioritize sustainability, resilience, and environmental stewardship through initiatives such as energy-efficient buildings, renewable energy sources, waste reduction, water conservation, green spaces, and eco-friendly transportation options. These efforts aim to minimize environmental impact, mitigate climate change, and enhance the overall quality of life for residents [94].

- Triple Bottom Line Approach:

1. **Economic Sustainability:** Focuses on fostering economic growth, promoting innovation, creating job opportunities, and ensuring equitable access to economic resources and opportunities for all residents [95].
 2. **Social Sustainability:** Emphasizes social inclusivity, equity, and quality of life. This involves ensuring access to essential services (healthcare, education, housing), promoting social cohesion, and addressing inequalities to enhance the well-being of all residents, including vulnerable and marginalized populations [96].
 3. **Environmental Sustainability:** Aims to minimize environmental impact, reduce carbon emissions, preserve natural resources, promote renewable energy sources, and implement sustainable practices in areas like waste management, transportation, and urban planning to mitigate climate change and environmental degradation [97].
- **Key Components of Smart City Sustainable Development:**
 1. **Green Infrastructure:** Implementing green infrastructure solutions such as green roofs, permeable pavements, urban parks, and sustainable drainage systems to manage stormwater, mitigate urban heat islands, enhance biodiversity, and improve air quality [98].
 2. **Resource Efficiency:** Promoting resource-efficient practices and technologies in areas like water management (recycling, rainwater harvesting), energy conservation (energy-efficient buildings, smart grids, renewable energy sources), and waste reduction and recycling to minimize resource consumption, waste generation, and environmental impact [99].
 3. **Community Engagement and Participation:** Engaging residents, businesses, civil society organizations, and other stakeholders in the planning, implementation, and monitoring of sustainable development initiatives to ensure inclusivity, transparency, and accountability [100].
 4. **Policy and Governance:** Developing and implementing supportive policies, regulations, incentives, and governance structures that facilitate sustainable development, innovation, collaboration, and investment in smart city initiatives [101].
 - **Benefits of Smart City Sustainable Development:**
 1. **Enhanced Quality of Life:** Improves public health, well-being, safety, and overall quality of life for residents by creating healthier, more resilient, and livable urban environments [102].
 2. **Economic Growth and Competitiveness:** Stimulates economic growth, fosters innovation, attracts investment, and enhances the competitiveness of cities by leveraging sustainable development opportunities and addressing emerging challenges [103].
 3. **Environmental Protection and Resilience:** Protects the environment, reduces carbon footprint, mitigates climate change impacts, enhances resilience to environmental hazards, and preserves natural resources for future generations [91,104].

3.2.5. Smart Transportation

Smart transportation is a pivotal component of smart cities, focusing on leveraging technology, data, and innovative solutions to enhance the efficiency, safety, sustainability, and accessibility of urban transportation systems [76]. Smart cities focus on improving transportation efficiency, reducing traffic congestion, and enhancing mobility options through initiatives such as intelligent traffic management systems, real-time public transit information, ride-sharing services, electric vehicles, bike-sharing programs, and pedestrian-friendly infrastructure. Smart transportation plays a crucial role in shaping the future of cities by integrating innovation, and sustainable practices to create efficient, accessible, safe, and environmentally friendly transportation systems that enhance mobility, connectivity, and quality of life for urban residents [105].

- **Key Features of Smart Transportation:**

1. Integrated Mobility Solutions: Integrating various modes of transportation, including public transit (buses, trains, trams), shared mobility services (ride-sharing, bike-sharing, car-sharing), pedestrian pathways, and cycling lanes to provide seamless, efficient, and multimodal transportation options for residents [106].
 2. Real-Time Data and Analytics: Utilizing sensors, GPS, IoT devices, and other technologies to collect real-time data on traffic conditions, transit operations, vehicle movement, passenger flows, and infrastructure performance to inform decision-making, optimize system operations, and improve user experience [107].
 3. Intelligent Transportation Systems (ITS): Implementing ITS technologies, such as smart traffic lights, adaptive signal control systems, dynamic tolling, electronic fare collection, real-time passenger information systems, and connected vehicle technologies, to enhance traffic management, reduce congestion, improve safety, and optimize transportation efficiency [76,107].
 4. Electrification and Sustainability: Promoting the adoption of electric vehicles (EVs), hybrid vehicles, and other clean and sustainable transportation solutions to reduce carbon emissions, improve air quality, and mitigate the environmental impact of transportation [108].
 5. Autonomous Vehicles: Exploring and integrating autonomous vehicles (self-driving cars, buses, shuttles) and connected vehicle technologies [89] to enhance safety, efficiency, and mobility for residents while addressing challenges related to traffic congestion, parking, and transportation accessibility.
- Benefits of Smart Transportation:
 1. Improved Efficiency and Accessibility: Enhances transportation efficiency, reduces travel times, optimizes route planning, and provides accessible and affordable transportation options for residents, commuters, and visitors [101,109].
 2. Enhanced Safety and Security: Improves road safety, reduces traffic accidents, mitigates risks, enhances emergency response capabilities, and creates safer transportation environments for all road users, including pedestrians, cyclists, and motorists [110].
 3. Environmental Sustainability: Reduces carbon emissions, promotes sustainable transportation solutions, enhances energy efficiency, and supports environmental conservation efforts to create cleaner, greener, and more sustainable urban environments [91,104].
 4. Economic Growth and Competitiveness: Stimulates economic growth, fosters innovation, attracts investment, enhances productivity, and improves the competitiveness of cities by creating efficient, resilient, and future-ready transportation systems that meet the evolving needs of urban populations [103].
 - Challenges and Considerations:
 1. Infrastructure and Investment: Requires significant investments in infrastructure upgrades, technology deployment, maintenance, and capacity building to support smart transportation initiatives and ensure long-term sustainability [66].
 2. Data Privacy and Security: Raises concerns related to data privacy, cybersecurity, data governance, and ethical considerations in managing, storing, sharing, and protecting sensitive transportation data and information [110].
 3. Equity and Inclusivity: Necessitates addressing equity, accessibility, affordability, and social inclusion considerations to ensure that smart transportation solutions benefit all residents, including vulnerable and underserved populations, and do not exacerbate existing inequalities and disparities [111].

3.2.6. Public Services and Governance

Smart city public services and governance encompass the strategic use of technology, data, collaboration, and innovation to enhance the delivery, accessibility, efficiency, transparency, and accountability of public services while fostering effective governance and citizen engagement. Smart cities leverage digital technologies to promote citizen engage-

ment through initiatives such as e-governance platforms, digital service delivery, open data portals, smart healthcare systems, emergency response systems, and public safety initiatives. Smart city public services and governance involve adaptive strategies to create more responsive, transparent, accountable, inclusive, equitable, and sustainable urban environments that meet the evolving needs and expectations of residents, businesses, and communities [112].

■ Smart Public Services:

1. Digital Transformation: Embracing digital technologies, platforms, and solutions to modernize and streamline public services, automate administrative processes, reduce bureaucracy, enhance service delivery, and improve user experience for residents, businesses, and visitors [78,113].
2. Citizen-Centric Approach: Adopting a citizen-centric approach to design, deliver, and evaluate public services by understanding and addressing the diverse needs, preferences, expectations, and feedback of residents and stakeholders through personalized, responsive, and accessible services [114].
3. Integrated Service Delivery: Integrating and coordinating services across various sectors, departments, agencies, and levels of government to provide seamless, holistic, and coordinated solutions that address complex challenges, optimize resources, and improve outcomes for individuals and communities [115].
4. Data-Driven Decision-Making: Leveraging data analytics, insights, and evidence-based practices to inform decision-making, prioritize investments, allocate resources, evaluate performance, monitor outcomes, and continuously improve the effectiveness and efficiency of public services [116].

■ Smart Governance:

1. Collaborative and Participatory Governance: Promoting collaborative, participatory, and inclusive governance models that engage residents, businesses, civil society organizations, and other stakeholders in the planning, implementation, monitoring, and evaluation of smart city initiatives, policies, and programs [117].
2. Transparency and Accountability: Enhancing transparency, accountability, integrity, and ethical standards in governance by promoting open data, public access to information, civic engagement, public scrutiny, oversight mechanisms, and mechanisms for redress and accountability [118].
3. Policy Innovation and Regulation: Developing and implementing innovative policies, regulations, incentives, standards, and frameworks that facilitate smart city development, technology adoption, innovation, entrepreneurship, collaboration, and sustainable growth while addressing emerging challenges, risks, and opportunities [119].
4. Capacity Building and Collaboration: Building institutional capacity, fostering interdepartmental collaboration, strengthening partnerships, networks, and alliances, sharing knowledge, resources, and expertise, and leveraging external support, funding, and technical assistance to enhance governance effectiveness, efficiency, resilience, and adaptability [120].

■ Benefits and Considerations:

1. Enhanced Service Delivery: Improves service accessibility, responsiveness, quality, efficiency, and user satisfaction by leveraging technology, innovation, data-driven approaches, and citizen engagement in designing, delivering, and evaluating public services [115,121].
2. Strengthened Governance: Enhances governance effectiveness, transparency, accountability, legitimacy, trust, public confidence, and social cohesion by adopting smart governance practices, promoting civic participation, fostering collaboration, and addressing governance challenges, risks, and opportunities [122].
3. Considerations: Necessitates addressing challenges related to the digital divide, privacy, security, equity, inclusivity, accessibility, capacity gaps, regulatory barriers,

governance structures, cultural change, stakeholder engagement, resource constraints, political will, and public acceptance in implementing smart city public services and governance initiatives [123].

3.2.7. Innovation Ecosystem

The smart city innovation ecosystem refers to the interconnected network of stakeholders, resources, organizations, policies, technologies, and initiatives that foster innovation, entrepreneurship, collaboration, and growth within smart cities. This ecosystem creates an environment conducive to generating, scaling, and implementing innovative solutions to address urban challenges and opportunities. Smart cities foster innovation and entrepreneurship by creating conducive environments for research, development, collaboration, and investment in technology-driven solutions. They support startups, incubators, accelerators, academic institutions, and industry partnerships to drive economic growth, job creation, and innovation in various sectors [124].

■ Key Components of Smart City Innovation Ecosystem:

1. **Stakeholders:** Engages a diverse range of stakeholders, including government agencies, local authorities, businesses, startups, academia, research institutions, non-profit organizations, community groups, residents, investors, and industry experts, to collaborate, co-create, and co-innovate solutions that address urban challenges and enhance city livability [125].
2. **Infrastructure and Resources:** Develops and leverages physical, digital, institutional, financial, human, and social infrastructure and resources, such as innovation hubs, co-working spaces, research labs, testbeds, accelerators, incubators, funding mechanisms, talent pools, networks, partnerships, and collaboration platforms, to support innovation activities, entrepreneurship, experimentation, and commercialization of smart city solutions [126].
3. **Policies and Regulations:** Establishes supportive policies, regulations, incentives, standards, frameworks, and governance structures that encourage innovation, entrepreneurship, investment, collaboration, experimentation, adoption of emerging technologies, sustainability, inclusivity, privacy, security, and ethical practices within smart cities [127].
4. **Technology and Data:** Embraces advanced and emerging technologies, such as IoT, AI, big data, cloud computing, blockchain, 5G, augmented reality, virtual reality, robotics, sensors, and smart devices, and harnesses data-driven insights, analytics, and intelligence to develop, deploy, manage, and optimize smart city solutions and services [128].

■ Dynamics of Smart City Innovation Ecosystem:

1. **Collaboration and Partnership:** Facilitates collaboration, partnership, knowledge sharing, co-creation, co-innovation, networking, and ecosystem development among stakeholders across sectors, disciplines, industries, and communities to leverage complementary strengths, expertise, resources, and capabilities to address urban challenges, drive innovation, and create shared value [129].
2. **Entrepreneurship and Startups:** Encourages entrepreneurship, startups, small and medium-sized enterprises (SMEs), innovators, and disruptors to develop, pilot, scale, and commercialize innovative solutions, products, services, business models, and technologies that address specific smart city needs, gaps, opportunities, and trends [130].
3. **Education and Talent Development:** Invests in education, training, skills development, capacity building, talent attraction, retention, and cultivation to foster a skilled, diverse, inclusive, and entrepreneurial workforce capable of driving innovation, technology adoption, economic growth, competitiveness, and sustainable development within smart cities [131].

■ Benefits and Considerations:

1. **Benefits:** Stimulates economic growth, job creation, entrepreneurship, investment, competitiveness, sustainability, resilience, livability, quality of life, citizen engagement, collaboration, creativity, problem-solving, innovation diffusion, adoption of best practices, and transformational change within smart cities and across regions, sectors, and communities [132].
2. **Challenges and Considerations:** Requires addressing challenges related to ecosystem fragmentation, silos, duplication, competition, scalability, sustainability, alignment, coordination, leadership, governance, funding, accountability, risk management, cultural change, stakeholder engagement, resistance to change, and ensuring that the smart city innovation ecosystem evolves, adapts, and thrives in a rapidly changing, complex, and interconnected global landscape [133].

3.2.8. Inclusive Growth

Smart city inclusive growth refers to the intentional and equitable development of urban areas that ensures all residents, regardless of their socioeconomic status, background, age, gender, ethnicity, or abilities, have access to opportunities, resources, services, and benefits that contribute to their well-being, prosperity, and quality of life. Smart cities strive for inclusive growth by ensuring equitable access to technology, services, opportunities, and resources for all residents, including marginalized and underserved communities. They focus on addressing social disparities, promoting digital literacy, enhancing accessibility, and fostering social cohesion through inclusive policies, programs, and initiatives. Smart city inclusive growth emphasizes the importance of prioritizing equity, accessibility, affordability, social cohesion, economic opportunity, quality of life, well-being, and community engagement in shaping the future of cities to ensure that all residents, communities, and stakeholders benefit from urban development, innovation, and sustainability in a fair, equitable, inclusive, and resilient manner that respects, values, and celebrates diversity, promotes social justice, and creates shared value for society as a whole [134].

■ Key Principles of Inclusive Growth in Smart Cities:

1. **Equity and Accessibility:** Prioritizing equity, accessibility, affordability, and inclusivity in urban planning, development, and governance to ensure that all residents have equitable access to essential services, infrastructure, amenities, opportunities, and resources, such as education, healthcare, housing, transportation, employment, public spaces, and digital connectivity [135].
2. **Social Cohesion and Integration:** Fostering social cohesion, integration, diversity, community engagement, participation, empowerment, and collaboration among residents, communities, stakeholders, and institutions to build trust, solidarity, resilience, and a sense of belonging within diverse urban populations and neighborhoods [136].
3. **Economic Opportunity and Mobility:** Promoting economic opportunity, mobility, entrepreneurship, innovation, skills development, job creation, inclusive growth, and social mobility by removing barriers, expanding access to education, training, employment, financial services, markets, networks, and support systems, and supporting diverse, sustainable, and inclusive economic development strategies and initiatives [137].
4. **Quality of Life and Well-being:** Enhancing the quality of life, well-being, health, safety, security, satisfaction, and life satisfaction of all residents by addressing social determinants of health, ensuring access to essential services, promoting physical and mental health, supporting healthy lifestyles, environments, and communities, and addressing social, economic, and environmental determinants of well-being [138].

■ Strategies and Approaches to Promote Inclusive Growth in Smart Cities:

1. **Community Engagement and Participation:** Engaging residents, communities, stakeholders, and marginalized and underserved populations in planning, designing, implementing, monitoring, evaluating, and adapting smart city initiatives, projects,

- programs, and services to ensure their needs, priorities, voices, and perspectives are heard, valued, and integrated into urban solutions and outcomes [139].
2. Collaboration and Partnerships: Building and strengthening collaborative, cross-sectoral, multi-stakeholder partnerships, networks, alliances, and ecosystems among government agencies, local authorities, private sector entities, civil society organizations, academic institutions, community groups, philanthropic organizations, international organizations, and other stakeholders to leverage complementary strengths, expertise, resources, and capabilities to address urban challenges, achieve shared goals, and create collective impact [140].
 3. Data and Technology: Leveraging data, technology, digital solutions, innovation, and evidence-based approaches to inform decision-making, improve service delivery, optimize resource allocation, measure progress, monitor outcomes, evaluate impact, and continuously enhance the effectiveness, efficiency, responsiveness, inclusivity, and sustainability of smart city initiatives, interventions, and investments [141].

3.3. Phases of Smart Cities

The development of a smart city typically involves multiple phases that encompass planning, implementation, integration, evaluation, and continuous improvement. The phases of a smart city encompass strategic planning, governance, infrastructure development, technology deployment, data management, integration, collaboration, pilot testing, evaluation, scaling, replication, and continuous improvement. These phases require coordinated efforts, multi-disciplinary expertise, stakeholder engagement, adaptive leadership, and sustained commitment to realize the vision, goals, and potential benefits of becoming a smart city [142]. While the specific phases may vary depending on the city's context, goals, and priorities, the following are commonly recognized phases in the journey toward becoming a smart city:

3.3.1. Vision and Strategy Development

Define the vision, goals, and priorities for becoming a smart city. Conduct a needs assessment, stakeholder analysis, and gap analysis to identify opportunities, challenges, and requirements. Develop a comprehensive smart city strategy, roadmap, and action plan that aligns with the city's objectives, resources, and timelines [143].

3.3.2. Planning and Governance

Establish a dedicated smart city governance structure, including leadership, coordination, and collaboration among various stakeholders, such as government agencies, private sector partners, academic institutions, and community organizations. Develop policies, regulations, standards, and guidelines to guide smart city initiatives, ensure compliance, and protect privacy, security, and data integrity [144].

3.3.3. Infrastructure and Technology Deployment

Invest in foundational infrastructure, such as broadband networks, communication systems, sensors, IoT devices, and data centers, to enable connectivity, data collection, and digital services. Implement smart technologies and solutions across key sectors, including transportation, energy, water, waste management, public safety, healthcare, education, and governance, to enhance efficiency, sustainability, and quality of life [145].

3.3.4. Data Management and Analytics

Establish data governance policies, protocols, and frameworks to manage, secure, integrate, and analyze data collected from various sources, including sensors, systems, devices, and platforms. Develop data analytics capabilities, machine learning algorithms, and AI-driven insights to derive actionable intelligence, optimize decision-making, and improve service delivery across the city [146].

3.3.5. Integration and Collaboration

Integrate disparate systems, platforms, and data sources to create a cohesive, interoperable, and scalable smart city ecosystem. Foster collaboration, partnerships, and engagement among public and private sector stakeholders, academic institutions, research organizations, and community groups to leverage collective expertise, resources, and innovation [147].

3.3.6. Pilot Projects and Demonstrations

Implement pilot projects, demonstrations, and proof-of-concept initiatives to test, evaluate, and refine smart city technologies, solutions, and strategies in real-world environments. Monitor performance, collect feedback, and assess outcomes to identify best practices, lessons learned, and areas for improvement [148].

3.3.7. Evaluation and Monitoring

Evaluate the impact, effectiveness, and return on investment (ROI) of smart city initiatives, programs, and projects based on predefined metrics, indicators, and benchmarks. Monitor progress, measure outcomes, and assess performance regularly to inform decision-making, prioritize resources, and adjust strategies as needed [149].

3.3.8. Continuous Improvement and Innovation

Foster a culture of continuous improvement, innovation, and adaptation to leverage emerging technologies, trends, and opportunities. Engage stakeholders, solicit feedback, and iterate on smart city strategies, policies, and initiatives to address evolving needs, challenges, and priorities [150].

3.4. Smart Cities Standards

The development of smart city standards by organizations like the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) is crucial in ensuring the effective and resilient implementation and management of smart cities. These standards play a critical role in guiding cities through the complex process of becoming smart cities, helping them to address challenges in a systematic and coordinated way.

3.4.1. Interoperability

Challenge: Different cities might use different technologies, platforms, and data formats. Ensuring that these systems can work together seamlessly is a significant challenge.

ISO/IEC Response: Standards like ISO 37120 [151] (Sustainable cities and communities—Indicators for city services and quality of life) and IEC 63152 (Smart cities—Smart city system roles) help define common frameworks and protocols to promote interoperability.

3.4.2. Data Security and Privacy

Challenge: The vast amount of data collected and processed in smart cities raises concerns about data security and privacy. Protecting sensitive information from cyber threats is critical [152].

ISO/IEC Response: ISO/IEC 27001 (Information security management systems) provides guidelines for establishing, implementing, maintaining, and continually improving an information security management system. ISO/IEC 27701 extends this to include privacy management.

3.4.3. Sustainability

Challenge: Smart cities aim to be sustainable, but balancing technological advancements with environmental impacts is complex [153].

ISO/IEC Response: ISO 37101 (Sustainable development in communities—Management system for sustainable development) sets out the principles and requirements for a management system that helps communities achieve sustainable development goals.

3.4.4. Standardization Across Regions

Challenge: Different regions may have varying needs, resources, and regulations, making it difficult to apply a one-size-fits-all standard [154].

ISO/IEC Response: ISO/IEC standards often provide a flexible framework that can be adapted to different local contexts. For example, ISO 37106 provides guidelines for establishing citywide strategies and approaches that can be customized.

3.4.5. Governance and Stakeholder Engagement

Challenge: Effective governance and engagement with a wide range of stakeholders (citizens, businesses, governments) are essential for smart city initiatives.

ISO/IEC Response: ISO 37104 provides guidance on governance and establishing strategies for the transformation into a smart city, ensuring that all stakeholders are involved in decision-making processes.

3.4.6. Measurement and Benchmarking

Challenge: Measuring the success of smart city initiatives and benchmarking against other cities can be difficult without standardized metrics.

ISO/IEC Response: ISO 37120 outlines a set of standardized indicators that cities can use to measure and compare their performance in various areas, such as economy, education, energy, environment, and governance.

3.4.7. Technology Evolution

Challenge: The rapid pace of technological change means that standards can quickly become outdated.

ISO/IEC Response: The ISO and IEC are continuously revising and updating their standards to keep pace with new developments in technology and urban planning.

3.5. Examples of Smart Cities

There are many smart cities around the world that are implementing advanced technologies to improve the quality of life of their citizens, increase sustainability, and enhance the efficiency of the city. To develop smart cities, there are three open-ended phases defined as Smart City 1.0, Smart City 2.0, and Smart City 3.0, as well as Smart City 4.0 [155] inspired by economics.

3.5.1. Smart City 1.0

The concept of “Smart City 1.0” generally denotes the preliminary stage of the smart city evolution. In this phase, cities start to investigate and integrate digital technologies, data-centric methods, and creative solutions to tackle urban issues and enhance residents’ living standards. Smart City 1.0 is marked by basic initiatives, trial projects, and initial implementations that set the foundation for more sophisticated and comprehensive smart city approaches in later stages [150]. Smart City 1.0 focuses on initiating pilot projects, demonstrations, and proof-of-concept efforts to assess innovative technologies in real urban settings. These projects target specific areas like transportation, energy, waste management, safety, and healthcare to showcase viability, efficiency, and scalability.

3.5.2. Smart City 2.0

While “Smart City 2.0” lacks a universal definition, it typically signifies a more sophisticated stage in smart city evolution. In this stage, cities advance from the initial efforts of Smart City 1.0 by incorporating advanced technologies, comprehensive strategies, and novel methods to tackle intricate urban issues and opportunities. Smart City 2.0 prioritizes integration, scalability, sustainability, inclusivity, resilience, and placing citizens at the core [156]. Smart City 2.0 prioritizes the seamless integration of various systems, technologies, and services across multiple sectors, aiming to establish a unified and scalable smart city environment. Cities harness integrated platforms, application programming

interfaces (APIs), middleware, and cloud solutions to ensure smooth connectivity and collaboration among stakeholders, devices, and systems. The Smart City 2.0 approach emphasizes leveraging data-driven methods, advanced analytics, machine learning, and AI to derive actionable insights, enhance operations, and guide strategic decisions.

3.5.3. Smart City 3.0

The third phase of smart city development is characterized by a focus on innovation, resilience, and adaptability in the face of emerging challenges and opportunities. During Smart City 3.0, cities are leveraging emerging technologies, such as blockchain, the IoT, and autonomous systems, to create more resilient and adaptive urban environments. This includes the use of smart infrastructure systems, such as self-healing power grids and automated water management systems, to enhance the reliability and resilience of critical urban services. Another key feature of Smart City 3.0 is the use of innovation ecosystems and digital innovation hubs to foster innovation and entrepreneurship in urban areas. This includes the establishment of co-working spaces, incubators, and accelerators to support startups and small businesses, as well as the integration of universities and research institutions into the urban innovation ecosystem [157]. Smart City 3.0 could involve a hyperconnected infrastructure ecosystem where everything is seamlessly integrated, interconnected, and intelligent, leveraging 5G/6G networks, quantum computing, edge computing, blockchain, Internet of Things (IoT), and other advanced technologies to enable real-time data sharing, collaboration, and decision-making across various domains and sectors.

3.5.4. Smart City 4.0

This is a theoretical concept that refers to the next phase of smart city development beyond Smart City 3.0. While Smart City 4.0 is not yet fully defined, it is expected to build on the foundations of previous phases and further integrate emerging technologies, such as artificial intelligence, 5G networks, and edge computing, to create even more intelligent, responsive, and interconnected urban environments. It is likely to focus on creating highly personalized and immersive experiences for citizens and visitors, utilizing virtual reality (VR) and augmented reality (AR) technologies [158], and the development of smart spaces that adapt to individual needs and preferences. It is also expected to involve greater collaboration between cities and private sector partners, as well as more decentralized and distributed models of governance [159]. Smart City 4.0 could emphasize the holistic integration, convergence, and interoperability of various systems, technologies, sectors, domains, and stakeholders within a unified, interconnected, and adaptive urban ecosystem. Cities might leverage advanced integration platforms, digital twins, cyber-physical systems, and ecosystem thinking to facilitate seamless collaboration, coordination, communication, and synergy across the entire urban landscape [159].

4. Results

We have strengthened the empirical foundation of this study by incorporating data-driven insights. This includes a detailed analysis of Egypt's current urban infrastructure, derived from government reports, city-level surveys, and international smart city benchmarks. The data highlight key areas of strength and weakness in Egypt's cities, such as existing technological capabilities, infrastructure development, and the governance framework. For example, the survey results from urban planners in Cairo and Alexandria reveal differing levels of readiness based on available technological resources and administrative capacities. These empirical findings are used to validate the theoretical framework outlined in the early sections of the paper and provide concrete evidence to support our conclusions. This approach moves the study beyond theoretical speculation, grounding it in real-world data that reflects the current status of Egyptian cities and their potential for smart city transformation.

4.1. New Cairo City

New Cairo, designated as a leading new urban center in Egypt, is classified as a third-generation city. It was developed to address population growth in Greater Cairo by creating attractive areas for expansion. Located east of Greater Cairo, New Cairo enjoys an elevation of approximately 350 m above sea level and features a moderate climate throughout the year. The city was established by Presidential Decree No. 191 in 2000, with construction commencing in the same year [160].

4.1.1. Economic Attributes of the City

In 2007, New Cairo experienced rapid urban expansion, driven by the relocation of key administrative services and the establishment of commercial hubs, universities, and schools. This growth prompted a comprehensive study on potentially relocating some ministries from Cairo to New Cairo, aiming to designate it as a central administrative hub. The emphasis was on respecting the planning and administrative parameters of New Cairo throughout this transition. The city's attractiveness continued to grow, leading to extensions in its surrounding areas as well [161].

4.1.2. City Analysis Through the Proposed Computer Program

The research assessed the readiness of the city for digital transformation using a proposed approach, likely involving a table or framework with relative weights assigned to various standards or criteria. According to Figure 4, the city achieved a relative weight of 0.780, which translates to 78%. This percentage indicates a high level of readiness for digital transformation, especially commendable for a new city categorized as a third-generation city. To enhance the city's readiness standards for digital transformation further, attention should be directed towards monitoring and improving key points identified in the assessment. This approach aims to increase the city's preparedness and achieve even higher levels of digital transformation readiness.



Figure 4. New Cairo city analysis through the proposed computer program.

4.1.3. New Cairo City Recommendations

- Enhancing the city administration and training administrative staff in modern technologies and IT systems facilitates efficient management and administrative services for residents.

- Upgrading and restructuring city infrastructure to align with rapid advancements in information technology and increased internet usage across various sectors.
- Leveraging the city's high average per capita income and economic growth to establish recycling plants, addressing air and water pollution issues.
- Establishing an administrative and organizational framework through city strategy development, defining roles, responsibilities, needs, and priorities, and enhancing institutional capabilities for continuous resident engagement.
- Continuously developing and optimizing city infrastructure and facilities, including efficient transport networks and interchanges.
- Implementing comprehensive urban development by expanding green spaces, public squares, and cultural and social activity areas.
- Enhancing main and secondary road networks to accommodate bicycles and pedestrians.
- Strengthening city infrastructure by increasing treatment plant capacities, adopting green infrastructure, promoting renewable energy sources, and maintaining telecommunications networks.
- Ensuring rapid and effective emergency response through early warning systems, enhancing healthcare and social support capacities.
- Encouraging resident participation in digital government platforms for civic engagement, decision-making, and resource management.
- Developing and enhancing city communication and information networks, including transport, security, and telecommunications infrastructure.

4.2. New Assiut City

The new city of Assiut is among the third-generation urban developments aimed at redistributing the population within Assiut Governorate and enhancing their quality of life. It features major initiatives led by the new Assiut Barrage, designed to significantly boost investments and tourism. Established under Presidential Decree No. 194 of 2000, the city represents a key project of the Urban Communities Authority in southern Egypt. Its objective is to enhance living standards for Upper Egypt residents through modern housing and infrastructure planning while also leveraging the region's skilled workforce [162].

4.2.1. Economic Attributes of the City

The volume of investments in the new city of Assiut is about EGP 38 billion, divided into several aspects: the utilities sector with EGP 9 billion, the housing sector with EGP 1.6 B, the services sector with EGP 3.8 B, and projects providing residents with all the material and logistical needs, such as the new Assiut barrage, the most important project after the High Dam. The new city of Assiut also contains a technology park (Silicon Oasis) with an area of 206.000 square meters, and the city offers companies operating in technology parks a wide range of valuable benefits that include advanced infrastructure and services for the business sector. Silicon Oasis also provides environmentally friendly spaces and sites that are committed to daily maintenance that creates an ideal working environment [163].

4.2.2. City Analysis Through the Proposed Computer Program

Research has measured the readiness of cities for digital transformation (through the table of relative weights of standards). As shown in Figure 5, we found that the city achieves a relative weight of 0.510, i.e., 51%, which is a rather weak percentage for an existing new city, and the most important points that can be paid attention to can be monitored to increase the value of the city's readiness standards for digital transformation and achieve it further.



Figure 5. New Assiut city analysis through the proposed computer program.

4.2.3. New Assiut City Recommendations

- Developing the city's administration and training its administrative cadres to use modern technologies and information technology gives the opportunity to develop management systems in the city and administrative facilitation for the residents.
- Redevelopment and restructuring of the city's infrastructure to keep pace with the great development in information technology and the significant increase in the use of the Internet in all fields.
- Increasing the city's power plants to raise the efficiency of their electrical readiness.
- Develop an administrative and organizational framework through the development of the city's strategy, defining roles, responsibilities, needs, and priorities for the city, preparing the timetable, developing the institutional capabilities of the city's administrations in order to communicate continuously with the city's residents, using modern technology in all aspects of the city's services, developing the infrastructure and transportation network, and providing government services within the city instead of moving to other cities.
- Applying comprehensive urban development through the development of and an increase in the number and areas of green spaces, public squares, and places for practicing cultural and social activities and developing the network of streets and roads to provide the necessary spaces for pedestrians.
- Providing urban spaces to increase social integration among members of society and increase cultural awareness of the importance of social integration among individuals through the work of cultural events, public and periodic seminars, and awareness banners.
- Strengthening the infrastructure by increasing the capacity of treatment plants, shifting towards green infrastructure, providing alternative sources of water, sewage, and energy supply, relying on renewable energy, and developing and maintaining the infrastructure network [164,165].
- Rapid and effective response by ensuring access to early warning systems on risks and increasing the capacity of health and social care homes.
- Developing the status quo, including the development of means of communication, transportation, means of security, and pedestrian places on the roads and the design of urban places in the city in a way that comforts the population, and increases their belonging to God is a religion (public squares–streets–green areas–heritage areas) and

attention to the element of beauty in the city to pay attention to the psychological aspect of the population.

4.3. Alexandria

Alexandria was selected to exemplify large, established cities that are not focused on growth. It is Egypt's second capital, a crucial port on the Mediterranean Sea, and a major center of economic activity. Historically, it served as the capital, and today it remains the capital of Alexandria Governorate and its largest city.

4.3.1. Economic Attributes of the City

The city of Alexandria benefits from a diverse economic foundation that encompasses industry, agriculture, tourism, a favorable climate, and vacant lands surrounding its urban area. These elements, along with available services, can drive development and attract investments. Additionally, Alexandria boasts around 189,000 acres of agricultural land and new areas rich in various economic resources, including human resources, tourism, archaeological sites, water resources, and port industries. The availability of services at both regional and city levels supports the city's sustainable development.

4.3.2. City Analysis Through the Proposed Computer Program

Based on the research conducted to measure the readiness of cities for digital transformation using the proposed approach and computer program (via the table of relative weights of the criteria), it was found that Alexandria achieves a relative weight of 0.590, or 59%, as illustrated in Figure 6. This is a commendable percentage for a large, established city. The city is undergoing continuous development, and the state is actively implementing projects with future plans, such as the "New General Strategic Plan for the City of Alexandria 2032". This plan is being executed by the Ministry of Housing in collaboration with the General Authority for Urban Planning and the Alexandria Governorate Regional Center for Comprehensive Development. Smart proposals for the city are also being developed. The computer program outputs offer key recommendations to enhance the city's readiness for digital transformation and increase its standards further.

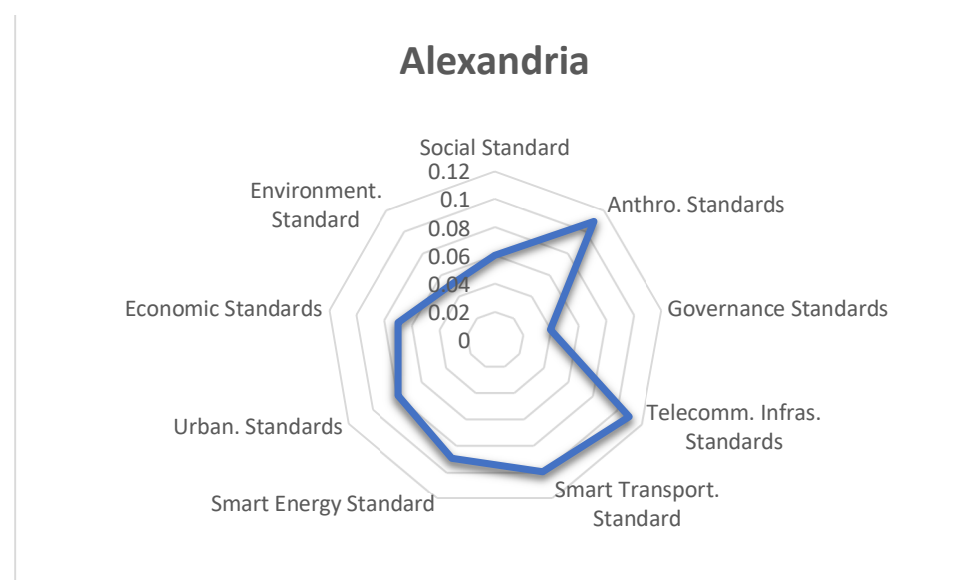


Figure 6. Alexandria city analysis through the proposed computer program.

4.3.3. Alexandria City Recommendations

- Redeveloping and restructuring the city's infrastructure to keep pace with the great development in information technology and the significant increase in the use of the Internet in all fields.

- Establishing several waste and wastewater recycling plants and seawater purification plants.
- Increasing the city's electricity distribution stations to increase the efficiency of its electrical readiness.
- Establishing alternative routes to the various areas and neighborhoods of the city to avoid traffic congestion and create the required fluidity.
- Increasing green spaces and gathering places for residents to perform social activities to achieve communication and build relationships.
- Increase public transportation buses and allocate paths for them and bicycles.
- Developing and raising the efficiency of roads and improving the easy drainage of rainwater.
- Stopping all construction work in the heart of the city and its extensions, whether horizontal or vertical, to reduce density there and preserve its infrastructure and facilities.
- Monitoring traffic in the city center and using the smart traffic management system more to avoid accidents.
- Using modern technology in all aspects of city services and developing the infrastructure and transportation network.
- Implementing comprehensive urban development through developing and increasing the number and areas of green spaces and developing the network of streets and roads to provide the necessary spaces for pedestrians.
- Strengthening the infrastructure, shifting towards green infrastructure, providing alternative sources of water supply, sewage, and energy, and relying on renewable energy.
- Rapid and effective response to emergencies by ensuring the access of early warning systems.

5. Discussions

The discussion section interprets the findings from the empirical analysis and relates them to the research objectives. One key insight is the gap between technology adoption and governance readiness, which presents a significant challenge for Egyptian cities in their transition to smart cities. The discussion highlights how the cities of Cairo and Alexandria, while equipped with some advanced technologies, lack the necessary governance structures to fully implement smart city initiatives. Additionally, we compare Egypt's readiness with other cities globally that have successfully transitioned into smart cities, such as Barcelona and Singapore, to illustrate where Egypt falls short and where improvements can be made. The discussion also reflects on the theoretical implications of the research, particularly how the Smart Cities Maturity Model applies to the Egyptian context. This section not only provides an in-depth analysis of the results but also connects them to broader urban planning strategies and global trends in smart city development.

The study assessed the city's readiness for digital transformation using a proposed method, likely involving a framework that assigns relative weights to various standards or criteria. As depicted in Figure 4, New Cairo achieved a relative weight of 0.780, or 78%, indicating a high level of digital transformation readiness, especially impressive for a new city classified as a third-generation city. In contrast, Figure 5 shows that New Assiut city attained a relative weight of 0.510, or 51%, signifying a relatively low level of readiness for a new city. Figure 6 reveals that Alexandria achieved a relative weight of 0.590, or 59%, a notable percentage for a large, established city. Alexandria is continuously developing, with the state actively implementing projects and planning for the future, such as the "New General Strategic Plan for the City of Alexandria 2032". As shown in Figure 7, New Cairo outperforms the other two cities in all standards except for economic standards, where Alexandria surpasses both New Cairo and New Assiut.

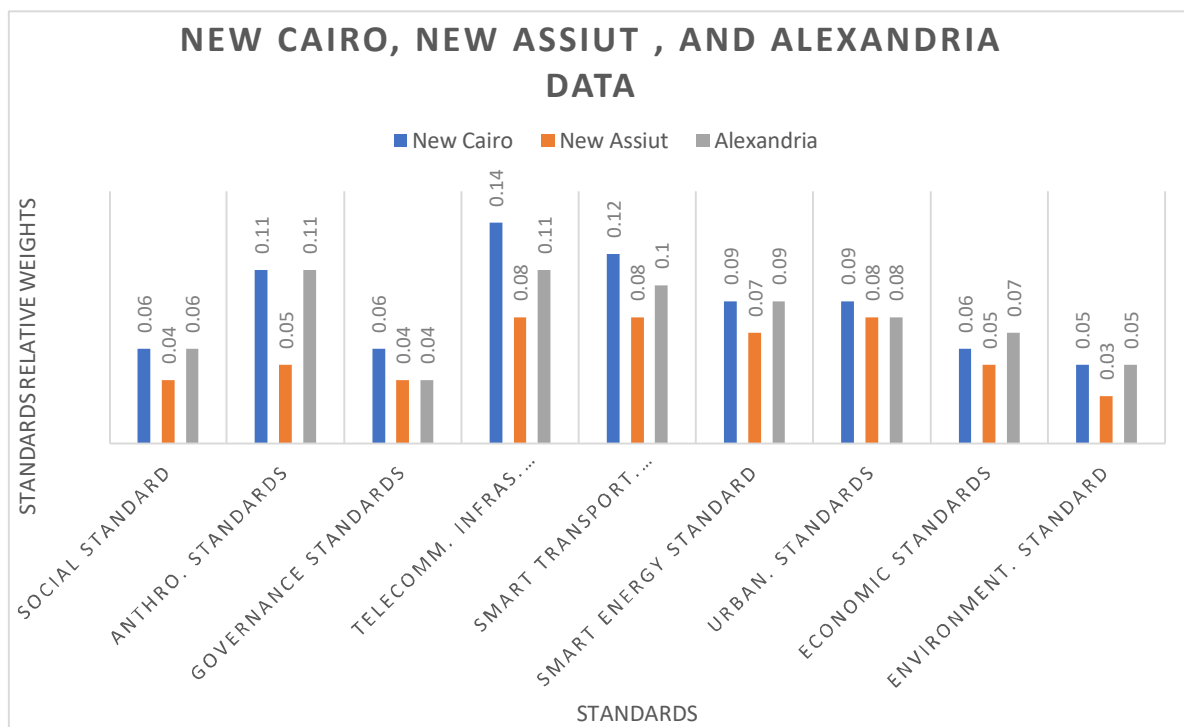


Figure 7. Comparison between New Cairo, New Assiut, and Alexandria cities.

6. Conclusions

Applying the proposed approach to the cities under study revealed varying degrees of readiness for digital transformation, with each city exhibiting unique characteristics that distinguish it from the other cities. This observation led to the identification of specific mechanisms tailored to each city, which can be presented to decision-makers to guide appropriate planning decisions. To achieve the research objective of formulating a theoretical model for cities' readiness for digital transformation within an applied framework, researchers developed a computer program. This program serves to measure cities' readiness for digital transformation and was formulated based on the reviewed theoretical and applied framework presented in previous chapters. The applied approach was utilized to implement this program in the cities under study. The analysis has demonstrated that a city's readiness for smart city initiatives hinges on several key elements, including technological infrastructure, governance frameworks, citizen engagement, and sustainability considerations. By measuring these factors, cities can identify their strengths and weaknesses, thereby enabling more targeted and effective strategies for development.

Egypt's experience highlights the importance of a tailored approach, considering the unique social, economic, and cultural contexts of the region. While the country has made significant strides in enhancing its urban infrastructure and digital capabilities, challenges remain in areas such as data governance, public awareness, and resource allocation. The successful transition from a traditional city to a smart city in Egypt, or any other context, requires a holistic approach that integrates technological innovation with human-centric design and sustainable practices. By adopting standardized measurement frameworks and leveraging global best practices, cities can ensure that their smart city initiatives not only enhance efficiency and convenience but also contribute to the overall well-being and resilience of their communities. As cities in Egypt continue to evolve, the lessons learned from this study can serve as a valuable guide for policymakers, urban planners, and stakeholders committed to building smarter, more sustainable urban environments. In the future, we plan to apply this software to other cities globally. To validate the software, we will apply it to current smart cities and input its parameters before conversion.

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