Jumpstarting the Digital Revolution: Exploring Smart City Architecture and Themes

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Abstract
Over the last few decades, various innovative technologies have emerged that have significantly contributed to making life easier for humans. Various information and communication technologies (ITCs) have emerged as a result of the global technological revolution, including big data, IoT, 4G and 5G networks, cloud computing, mobile computing, and artificial intelligence. These technologies have been adopted in urban planning and development, which gave rise to the concept of smart cities in the 1990s. A smart city is a type of city that uses ITCs to exchange and share information to enhance the quality of services for its citizens. With the global population increasing at unprecedented levels, cities are overwhelmed with a myriad of challenges, such as the energy crisis, environmental pollution, sanitation and sewage challenges, and water quality issues, and therefore, have become a convergence point of economic, social, and environmental risks. The concept of a smart city is a multidisciplinary, unified approach that has been adopted by governments and municipalities worldwide to overcome these challenges. Though challenging, this transformation is essential for cities with differing technological and social features, which all have the potential to determine the success or failure of the digital transformation of cities into smart cities. In recent years, researchers, businesses, and the government have all turned their attention to the emerging field of smart cities. Accordingly, this paper aims to represent a thorough understanding of the movement toward smart cities. The key themes identified are smart city definitions and concepts, smart city dimensions, and smart city architecture of different layers. Furthermore, this article discusses the challenges and some examples of smart cities.

Keywords:
Smart city, Digital transformation, ITCs, Governance, Sustainability. Smartness

I. Introduction

Rapid urbanization, increasing population growth, technological advancements, and economic trends are responsible for changing cities and their entire structures, converting them into great urban centers. Cities are the center of economic activities that result in economic, social, and cultural benefits (Fernandez-Anez, Fernández-Güell & Giffinger, 2018) and are the hub of economic growth and development through production and consumption globally, thus contributing toward the gross domestic product (GDP) (Ramaprasad, Sánchez-Ortiz & Syn, 2017). They have grown at unprecedented rates since the Industrial Revolution, which also indicates the growth of the global population at an alarming pace. The United Nations (2022) reported that the global population reached 8 billion in 2022, with an expected increase of two billion people by 2050 (United Nations, 2022). According to the reports of the World Bank (2019), the global population has been projected to grow by 1.5 times by the year 2045 with an 80% increase in GDP production, which will primarily come from urban areas (The World Bank, 2019; Hasija, Shen & Teo, 2020). Based on the reports compiled by the World Health Organization, the global population will increase by 32% by 2050, with most of the population living in urban areas (Eremia, Toma & Sanduleac, 2017). Eremia, Toma & Sanduleac (2017) further reported that by 2030, most population growth will occur in Latin America, Africa, and Russia. According to Almulhim & Cobbinah (2022), the dramatic growth of the global population is attributed to increasing urbanization and migration.

Because of the urbanization process and better opportunities for education, employment, and social life provided by cities, people have gradually moved away from rural areas (Yin et al., 2015; Anthony, 2021). Urban areas offer a better standard of living, high-quality healthcare services, fast and efficient transportation systems, and accessibility to clean water systems (Yin et al., 2015). Consequently, governmental institutions and municipalities in both developed and developing countries emphasize allocating resources and funding to urban development compared to rural areas (Pandya et al., 2023). While the majority of people are urban residents, a scenario that offers a multitude of opportunities to individuals, there are several challenges associated with rapid urbanization, including high unemployment, traffic congestion, environmental degradation, water quality issues, water availability issues, air and noise pollution, overcrowding, health hazards, and increased crime rates (Camero & Alba, 2019; Sánchez-Corcuera et al., 2019; Wang & Li, 2021). Unquestionably, these challenges could convert cities into convergence points of economic, social, and environmental risks, resulting in inadequate resources and services for their residents. Consequently, cities require significant

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modifications to fulfill the demands and requirements of the growing population through urban planning and development initiatives. Well-managed cities can significantly contribute to the enhancement of services provided to their residents while supporting economic and social development.

With the help of the smart city concept, both governments and municipalities have taken a unified approach to address these challenges. It emerged in the 1990s and has been extensively studied in the literature (Ramaprasad, Sánchez-Ortiz & Syn, 2017; Fernandez-Anez, Fernández-Güell & Giffinger, 2018). Smart cities rely heavily on technological advancements such as the Internet of Things (IoT), big data analytics, artificial intelligence, augmented and virtual reality, machine learning, cloud and mobile computing, and 4G and 5G networks that have grown in conjunction to rapid urbanization (Sánchez-Corcuera et al., 2019). These are used as urban planning and development methods as an alternative to conventional planning tools and techniques (Fernandez-Anez, Fernández-Güell & Giffinger, 2018). Cities are now using data management networks and cloud computing technologies, intending to improve the quality of life through improved services for their residents (Kirimtat et al., 2020).

This paper aims to present and discuss smart city concepts and interrelated terms through the analysis of previous literature that has been extracted through the use of several keywords, such as "Smart City, Smart City Concepts, Smart City Definitions, Smart City Dimensions, Smart City Challenges, Smart City Governance, Smart City Sustainability". This research uses more than 50 research papers published between 2015 and 2023 on various topics in the context of smart cities. To search for the relevant literature, Google Scholar was used. We also used other academic and scientific databases, such as ScienceDirect, IEEE Xplore, Web of Science, Sage Publications, and JSTOR. We have analyzed the concepts related to the smart city in context to the critical themes identified in our research. Therefore, we have conducted a literature search and review. Section II of this paper provides an overview of the definitions and concepts of a smart city in light of previous literature. Section III provides the dimensions of the smart city. The smart city architecture is presented in Section IV, while Section V views the characteristics of a smart city. Section VI represents the challenges of a smart city. Section VII shows a few instances of modern smart cities. Finally, Section VIII presents the conclusion.

II. Smart City Definitions and Concepts

The literature synthesis demonstrates that several attempts have been made to define the concept of a smart city over the years. However, the literature review also indicates that a smart city requires a standardized and well-defined definition acceptable to the academic community and related industries. According to Dameri et al. (2019), the concept of a smart city is “fuzzy” and vague. Nevertheless, prior studies have attempted to present their ideas of smart cities. An analysis of the literature demonstrated that it is a complex, multidisciplinary concept. Approaches to defining smart cities are also based on various factors, such as technological, human, and social factors (Dameri et al., 2019).

Differences between Conventional and Smart Cities

The key differences between conventional or traditional cities and smart cities have been elucidated in the works of Lom and Pribyl (2021) in the light of system theory. They stated that a complex system is created through interdependent and interlinked components. Every individual system has its temporal and spatial demarcations, which are influenced by the environment. The authors further reported that there are subsystems, which are independent and different components of the system. Therefore, a city is described as an extensive system comprising many human settlements with complex subsystems, such as transportation, housing, land, water services, or utilities (Lom & Pribyl, 2021). Based on the framework by Lom & Pribyl (2021), traditional cities are systems with independent subsystems that cannot communicate within their environment. Conversely, a smart city is a system with interactive subsystems through information and data exchange. For instance, intelligent transportation systems based on IoT networks and big data analytics are used to manage traffic and other systems to promote user safety and security (Saarika, Sandhya & Sudha, 2017; Jan et al., 2019).

Samarakkody, Kulatunga & Bandara (2019) attempted to define smart city(ies) by distinguishing between basic and smart cities. They clarified that a basic city is a type of city that requires innovative solutions for complex challenges, such as energy, transportation, safety, health, and utilities. Smart cities offer solutions to these challenges by collaborating with various stakeholders, including government agencies, municipalities, and private organizations (Samarakkody, Kulatunga & Bandara, 2019). The objective of adopting these solutions is to upgrade the city. They are designed to offer solutions to the current and emerging problems that basic cities face to improve residents' standard of living and promote development (Samarakkody, Kulatunga & Bandara, 2019).

Obando Bobadilla, Ruiz Nieto & Rodríguez Molano (2018) stated that the transformation of traditional cities into smart cities requires stakeholder collaboration, including public organizations, government, and citizens using innovative technologies aimed at improving services for its citizens.

Kumar & Rattan (2020) also highlighted the major differences between conventional and smart cities. They

reported that conventional cities have complex systems comprising various services such as healthcare, water and sewage services, education, energy, communication networks, transportation services, and related services and utilities (Kumar & Rattan 2020). As these cities grow, these services are inadequate to fulfill the demands of the growing system and add stress to the local environment and the economy. Conventional cities also use nonrenewable energy resources, which contributes to the energy crisis and greenhouse emissions. Furthermore, these cities need a proper system for managing and controlling different types of pollution. Alternatively, smart cities are urban cities that provide a good environment for their residents by adopting sustainable measures aimed at protecting the environment and maintaining safety and security by deploying ITCs (Kumar & Rattan, 2020). Moreover, smart cities function to offer better services to their citizens (Kumar & Rattan, 2020).

Smart City Definitions

Researchers have undertaken several approaches over the years to define the concept of the smart city. While the definitions vary significantly, they present an understanding of the concept. It is clearly evident that conventional and smart cities are substantially different in context due to the diffusion of ICTs in the latter, which enables them to enhance the services provided to their citizens. In a simplistic definition, Arroub et al. (2018) explained that a smart city is a system consisting of several systems that are operated intelligently. Dameri (2019) presented a more comprehensive definition and reported that it is a "well-defined" geographic territory that uses high-tech technological innovations to benefit its citizens by improving the level of services by aiding the city government in urban planning and development. A technology-based definition of the smart city was presented by Pandyastate et al. (2023). Pandya et al. (2023) stated that smart cities depend on the IoT and sensors used to collect information throughout the city. Information on traffic conditions, drainage, smart buildings, smart grids, and sixth-generation (6G) networks is collected and then analyzed using machine learning and deep learning techniques to make predictions that enable city planners to address the challenges of the city and enhance services for its citizens.

Umdu & Alakavuk (2020) stated that a smart city is an infrastructure heavily reliant on big data obtained from IoTs. The data are then analyzed to develop a sustainability-based model to aid economic and social development while promoting environmental protection. Anthopoulos (2015) also attempted to present the concept of the smart city. Based on his research, he stated that a smart city can be described based on four essential perspectives: technology, ecology, urban development and growth, and creative industry. The author reported that these four domains must converge to form a smart city, resulting in several smart city-related benefits aimed at addressing urban challenges. Similarly, Polyakov (2019) asserted that modern cities are significantly challenging and have, therefore, altered their approach in context to development. They have become more adaptive, resilient, and intelligent as they have incorporated digital technologies to create competitive digital ecosystems to support socioeconomic development. The remaining definitions of SC based on the analysis of previous studies are summarized in Table 1.

Table 1: Smart city definitions.

Authors	Smart city definitions
Ahad et al. (2020)	A smart city is a hopeful project, which aims at improving the lives of its inhabitants with the help of up-to-date technologies, automating the processes at all levels concerning governance and policy-making, and giving accessibility to end users with the help of smart devices.
Khan et al. (2020)	A smart city is the convergence of urban governance and ICTs by private and governmental agencies to enhance economic development and improve quality of life.
Laufs, Borrion & Bradford (2020)	A smart city is a safe city, which emphasizes adopting measures to keep it safe by adopting technological innovations aimed at reinforcing law enforcement agencies, enhancing the delivery of healthcare services, and improving disaster management.
Nikitas et al. (2020)	A smart city is an "interconnected and intelligent" urban space, which adopts ICTs to reduce service costs, enhance productivity, optimize resource consumption, and improve the standard of living for its residents.
Jasim, N., & ALRkabi (2021)	A smart city is an intelligent city, which helps develop, disseminate, and promote development practices based on sustainability to deal with the challenges associated with urban mobility.
Masik, Sagan & Scott (2021)	The smart city concept is the approach that supports urban development and sustainability adoption and reinforces urban resilience through decision-making that is democratic and resilient in nature.

Pašalić, Ćukušić & Jadrić (2021)	Smart cities are intelligent urban dwellings interconnected through ICTs, which enhance the quality of services and life for residents and adopt sustainable practices to protect the environment and manage natural resources.
Yahia et al. (2021)	A smart city is a collaborative network that supports government collaboration and promotes collaboration within different city networks through policy-making.
Haque, Bhushan & Dhiman (2022)	A smart city is a representation of establishing a sustainable city through ICTs, allowing its citizens access to various services through cyber intelligence, improving the quality of life for its citizens, and protecting the environment.
Duygan et al. (2022)	A smart city uses scientific technologies such as IoTs, big data, deep learning, and artificial intelligence to support infrastructure and municipal development to improve citizens' well-being and protect and preserve the environment.
Ismagilova et al. (2022)	A smart city is a term used to describe the utilization of technology-based solutions, which improve the lives of its citizens, enhance collaboration with the government, and foster sustainable growth and development.
Zhu, Shen & Ren (2022)	A smart city is a solution to socioeconomic and environmental challenges caused by rapid urbanization through embracing ICTs.

Based on the previous definitions, we can say that for cities to be smart, they need to have the following characteristics:

- Adoption of technologies as a prerequisite requirement for becoming a smart city
- Information and data exchange across different networks
- Sustainability to protect the environment and natural resources and to promote economic and social development.
- Supporting urban services and processes by enhancing their efficiency and reducing overall operational costs
- Promoting human safety and wellbeing

III. Smart City Dimensions

In general, dimensions are organized into six pillars that work and cooperate with each other, facilitating and increasing their contribution and participation in the city's development. Moreover, in achieving smart city goals, it is important to have efficiency, sustainability, and a high quality of life (Al-Ghabra, 2022). The concept of smart cities means that the city should be creative, offer a friendly environment, and be a sustainable area that enhances life quality (Winkowska et al., 2019). One of the significant features of smart cities is intelligence, which should not be taken literally but rather as the sum of multiple improvements in resources, public services, and urban infrastructure (Winkowska et al., 2019). Any city is considered a smart city if it has the following six elements or dimensions (Fig. 1).

1- Smart Economy:

The smart economy is measured by city productivity and entrepreneurship, labor market flexibility, and adaptation to change (Winkowska et al., 2019). The entrepreneurial, innovative, and productive city has a positive image and a flexible labor market that assures national and international collaborations (Szum, 2021). The smart economy can be studied from different perspectives. It involves policies and guidelines that trigger innovation and creativity associated with advanced technology, scientific research, and the sustainability concept. Arroub et al. (2016) defined a smart economy as one that features competitiveness, innovation, the use of ICTs in most aspects of the economy, and the social responsibility of resource use. Kumar & Dahiya (2017) mentioned that a smart economy is a knowledge economy based on advanced research in all disciplines, such as business, planning, science, architecture, industry, cultural heritage, and development. There are various forms and applications of the smart economy in smart cities, each having unique features, challenges, and solutions (Al Sharif & Pokharel, 2021).

2- Smart Mobility:

Appio et al. (2019) focused on infrastructure and transportation systems. They mentioned that common problems in cities are related to traffic, including delays, long queues, and congestion. Moreover, they recommended that smart cities must concentrate on private vehicle usage and provide several organized choices to ease people's mobility. The IoT is used to analyze prospective travelers' routing and collect real-time road data (Al Sharif & Pokharel, 2021). Smart mobility is about information accessibility and communication infrastructure by developing innovative, sustainable, and safe transport

(Winkowska et al., 2019). Ismagilova et al. (2019) showed that the connectivity of information in vehicles through IoT and the Internet of Vehicles (IoV) provides efficiency and traffic safety and subsequently leads to smart mobility. A better-integrated transportation system can be obtained through the widespread use of IoT in rural and urban areas (Al Sharif & Pokharel, 2021). Smart mobility provides a clean, efficient, and legal transportation network for citizens, goods, and data with the aid of technologies that collect and grant information to supervisors, managers, customers, and planners to have available and accessible services (Al-Ghabra, 2022).

3- Smart Environment:

The smart environment is measured by pollution levels, activities that protect the environment, resource management methods, and the attractiveness of the natural environment (Winkowska et al., 2019). Szum (2021) identified this concept as a city with a low pollution level, where energy consumption is optimized, alternative energy sources are provided, and some practices are forced to minimize the pressure on the environment. It is concerned about pollution, natural conditions, and resource management (recycling, reuse, and resource replacement) (Al-Ghabra, 2022). According to Appio et al. (2019), the smart environment includes energy management, improvements in waste discarding, smart grids, pollution control, quality of water and air, increases in green spaces, monitoring emissions, and house and facility management. IoT technologies are used to develop smart environment applications, and these technologies use several types of sensors to manage smart city environments, such as optical sensors, pressure sensors, radio frequency identification, and integrated circuits. The real-time data are collected to help the decision-makers optimize waste and junk collection, sorting, and recycling (Al Sharif & Pokharel, 2021).

4- Smart People:

It is very significant that the citizen participates in smart urban life to provide new and innovative solutions. Education is surely needed to achieve this dimension, and distance learning and online courses can also afford positive development results in smart cities (Al-Ghabra, 2022). Winkowska et al. (2019) stated that smart people are identified by their qualification level, creativity, social and ethnic diversity, lifelong learning, and openness and participation in public life. The social infrastructure of a smart city is basically dependent on human capital and social capital. Human capital is defined as the abilities and skills of a person or a group, while social capital is the number and quality of relations connecting social organizations. In smart cities, it is critical to have better human and social capital to obtain productivity and innovation; therefore, higher education institutions, such as universities, play a significant role in developing human capital development (Ismagilova et al., 2019). Higher education institutions act as knowledge mediators, sponsors, and providers of activities to aid people in becoming smart (Al Sharif & Pokharel, 2021).

5- Smart Living:

Smart living is characterized by living conditions (safety, health, and housing), existing cultural facilities, social cohesion, educational facilities, and tourist attractiveness (Winkowska et al., 2019). Arroub et al. (2016) mentioned that citizens use technology to develop intelligent ways of living, where connected devices enable most tasks to become safer, easier, and cheaper. Moreover, multiple innovative solutions are under development, targeting ways to make an individual's life more efficient, productive, and sustainable. Smart living involves some significant areas of the city, such as smart buildings, public safety, education, tourism, and healthcare, all of which enhance the quality of life for city citizens (Ismagilova et al., 2019). Healthcare in smart cities is obtained by emergency support enabled through ICT, real-time monitoring of special care needs, and home re-habitation applications that emerged during the COVID-19 pandemic to aid medical professionals. In addition, it can be said that smart living is an outcome of the smart economy (Al Sharif & Pokharel, 2021). The use of ICT also assists in smart living through networked and Internet-enabled automated living space conditioning, lighting, and connected security systems. Smart assistance applications are used mostly in smart homes. These applications collect personal and private data about their users, but some associated privacy and security risks are not solved yet (Al Sharif & Pokharel, 2021).

6- Smart Governance:

Smart governance is expressed by the level of public services, city management transparency, social participation, and the implementation of development strategies (Winkowska et al., 2019).

Al-Ghabra (2022) characterized smart governance as political participation, quality of public services, efficient public administration, and citizens' contribution to decision-making. This facilitates the coordination of all approved municipal activities involving ICT in electronic administration and stakeholders. In addition, some of the goals are to develop public services, satisfy people's needs, and increase the confidence of community institutions (Al-Ghabra, 2022). In smart cities, the role of governance entities is to collect/aggregate/process data related to value-added processes and to manage information flows among stakeholders. They may also enable financial mechanisms, authenticate data quality and integrity, generate internal and external awareness of smart city initiatives, and coordinate stakeholders (including citizens) throughout the value chain (Appio et al., 2019).

Silva et al. (2018) studied smart city dimensions and challenges and have illustrated that smart cities' governance is related to public services, social services, the contribution to decision-making, policies and strategies, and transparent governance. They mentioned governance as coordination between citizens and administrative institutions and noted that successful governance can help obtain the maximum benefits of smart cities in terms of efficiency, reliability, and effectiveness of citizens' services. They showed that technical governance is substantial in smart governance since it assures addressing all city features and services through high-tech technological solutions (Silva et al., 2018).

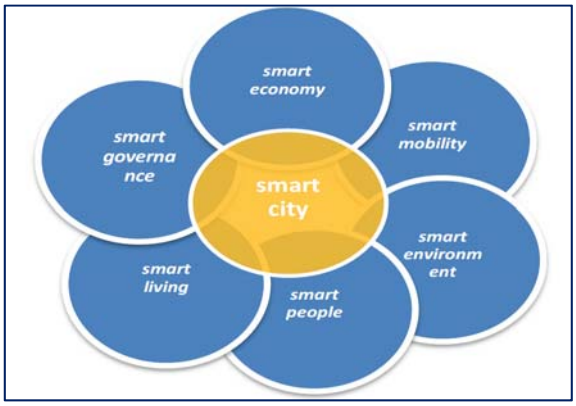

Fig.1. Smart city dimensions. Source: Winkowska et al., 2019.

IV Smart City Architecture

Singh et al. (2022) illustrated the bottom-up architecture, which consists of four layers: the detection layer (the sensing layer), the transmission layer, the data management layer, and the application layer (Fig. 2). One of the crucial issues in smart cities is sensitive data protection; therefore, the security modules are integrated into each layer. The main feature of the sensing layer is data collection from physical devices. The transmission layer is responsible for sending data to the upper layers through various communication technologies. Furthermore, the data management layer focuses on processing and storing important data that help to provide high levels of service provided by several applications (Singh et al., 2022).

1-Sensing Layer:

Smart cities include large amounts of data, data storage, composite designs, and intelligent executive capabilities. The researchers believed that smart city employment is very significant in the decision-making process because it authenticates all information and calculation procedures (Shah et al., 2019). Moreover, information gathering is the most substantial part of managing the operation of a smart city. Data gathering is a complex process because of the great diversity of the information collected. The mechanisms and technologies used for information collection are closely related to the context and type of the information (Singh et al., 2022). The smart city uses data involving different city operations, including epidemic management of personal health, disaster management, control of smart home devices to balance smart grid loads, and community waste management. As a result, the data generated by city operations makes these differences very marked. Also, generating large amounts of data complicates the data collection process (Singh et al., 2022). As shown in Fig. 2, the lower layer is the detection/information collection layer and contains various information gadgets that are used to capture huge amounts of information from multiple sensors (Gheisari et al., 2019). This layer collects environmental data such as humidity, temperature, motion, pollution level, location, and air pressure. Also, it collects data from machines and people (Saba & Sahli, 2020).

2- Transmission Layer:

The transmission layer is considered the primary support of smart city architecture. It is responsible for assembling several correspondence organizations. This layer incorporates multiple kinds of remote, wired, and satellite advancements. In addition, it is partitioned into two sublayers, access transport, and organization transport (Singh et al., 2022). This layer's work depends on several network technologies, including Bluetooth, Zigbee, near-field communication (NFC), M2M, RFID, Zwave, 3G, 4G (LTE), 5G, and low-force utilization (LP-WAN) (Li et al., 2016). Bluetooth uses short-frequency radio waves to reduce correspondence power utilization. Moreover, RFID technology uses the radio frequency (RF) part of the electromagnetic range to recognize vehicles, individuals, articles, or creatures. It is similar to a scanner tag framework as it can distinguish things from a distance. NFC is an entrance network innovation that facilitates correspondence between two gadgets with a distance of 10 cm in between. It implements acknowledgment while sharing data between NFC-empowered gadgets (Park et al., 2017). ZigBee allows for low-force correspondence between ZigBee-enabled devices up to a distance of 10 meters. LTE is the leading 4G remote service and has been characterized as better than 3G, Wi-Fi, and WiMAX in terms of high bitrate, low inertness, and fast (Cassandras, 2016). In portable organizations, 3G and 4G play a substantial function. Currently, in the fifth era (5G) of broadcast communications, cell networks are a trendy expression and operate through huge multi-input, multi-output (MIMO) radio wires integrated into the base station to send remote traffic at the gigabyte level. Another sort of transmission network is LP-WAN, which aims to improve the energy proficiency of mechanical organizations. In addition, it is a promising innovation for

future smart urban communities because it can reduce power utilization and has a broad scope of inclusion (Singh et al., 2022).

3- Data Management Layer:

The data management layer is the mind of a smart city. It is located between the sensing and the application layers. Moreover, this layer performs several activities, including storage, examination, association, and dynamic tasks. The administration and execution of smart city activities rely on information management. Therefore, expertise in information management is vital to a feasible smart city. The main assignment at the information level is to keep information dynamic, with attention being paid to cleaning, repairing, updating, and combining information (Shah et al., 2019). Information management can be divided into information combination, information preparation, stockpiling, occasion, and choice administration. Information combination integrates information from different sources to enhance exactness and enable clear choices without relying on a single information source. In a smart environment, information examination can improve the productivity of information preparation. Multiple techniques and strategies to perform information combinations will be discussed in detail later. As information investigation and handling cannot guarantee improved metropolitan execution, information storage plays an essential role and is needed to facilitate multifaceted and solid admittance of a lot of information (Gheisari et al., 2019). The responsibility of executives and choice administration parts is to organize the information gathered from various sources and information extracted from the information stored to plan the right choices. The last task of the data management layer is passing the conditional choices to the application layer and executing them (Singh et al., 2022).

4- Application Layer:

This layer is at the top of smart city architecture and acts as an intermediary between city residents and data management. Application-level performance directly affects the operator's perspective, audience, and fulfillment with smart city operations. Citizens are always looking for the provision of smart services in the smart city, such as smart weather forecasts. The application layer contains different components from several disciplines (Oughton et al., 2019). The functions of the main application layer include network provisioning, network improvement, smart transportation, and climate assessment. Moreover, this layer improves city execution through applications that perform information handling and storing. The advantages of sending independent, smart applications are little recognized in enhancing the presentation of metropolitan tasks (Singh et al., 2022). Therefore, sharing information between several applications is promising for smart urban development. The smart application makes decisions submitted by the data management layer. Furthermore, the information management layer is responsible for cleaning and processing the collected information to select the ideal insightful choice that organizes the specific circumstance. Subsequently, the application layer executes that choice when the information management layer chooses. Citizens do not understand the middle tier of data management, so their understanding of performance gains relies only on the application tier outcome (Saba & Sahli, 2020).

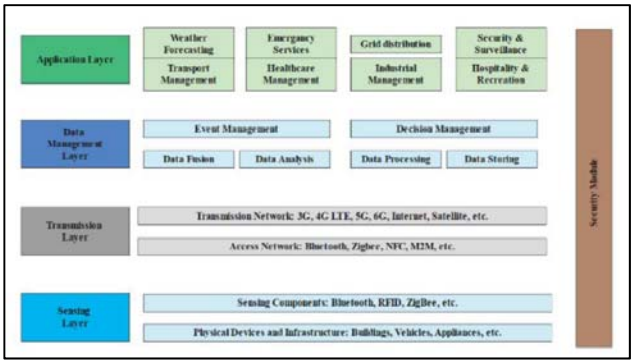

Fig.2. The architecture of the smart city.
Source: Singh et al., 2022.

V. Smart City Characteristics

According to the literature, various characteristics come together to build a smart city. According to Mohanty, Choppali & Kougianos (2016), a smart city has four main characteristics: smartness, sustainability, quality of life, and urbanization. These characteristics are further divided into subcharacteristics. For example, sustainability comprises the following attributes: pollution, infrastructure development, governance, economics, social challenges, climate change, and energy crisis (Yigitcanlar & Kamruzzaman, 2018). Quality of life is concerned with the financial and emotional welfare of the citizen. Urbanization focuses on the development aspects that help an area to shift from a rural environment to an urban environment through a series of strategies aimed at proving development at technological, economic, and infrastructural levels (Eremia, Toma & Sanduleac, 2017). Smartness refers to the attribute that enhances the city and its residents through environmental, social, and economic goals and objectives (Mohanty, Choppali & Kougianos, 2016, Zhu, Shen & Ren, 2022).

1- Sustainability

The concept of sustainability has been popular in relation to the urban development concept since the 1980s. In fact, sustainability contributes to developing the smart cities concept. In the context of sustainability, the triple bottom line notion has been adopted. The triple bottom line concept has successfully

drawn the link between sustainability characteristics (Yigitcanlar & Kamruzzaman, 2018). As cities are using natural resources at an alarming rate, nonrenewable resources are experiencing worldwide shortages, which are contributing to the energy crisis and energy inefficiencies. Furthermore, the use of nonrenewable energy resources is also responsible for contributing to greenhouse emissions, climate change, and ozone layer depletion (Mozūriūnaitė & Sabaitytė, 2021). As a result, protecting energy resources and the environment from human activities is essential for existing and future generations while adopting innovative measures to enhance economic development and growth (Zhu, Shen & Ren, 2022). The Amsterdam Smart City project is considered to be one of the global smart city initiatives, where the government, business institutions, educational enterprises, and citizens have come together to reduce carbon emissions and enhance the overall environment (Angelidou, 2016, Angelidou, 2017, Bolici & Mora, 2015, Capra, 2016).

2- Quality of Life

Quality of life is the primary agenda of smart cities through the adoption of innovative technologies and solutions to reduce the restrictions and barriers associated with social learning and participation. Under quality of life, smart city initiatives aim at developing the following facilities and services: healthcare services, housing quality, tourist activities, historical monuments restoration, educational facilities, renewable energy services, crime rates reduction, and social cohesion (Zhu, Shen & Ren, 2022, Zubizarreta, Seravalli & Arrizabalaga, 2016). By enhancing these facilities, a smart city can successfully adopt ICTs to improve the quality of life for its residents. Moreover, the role of governmental agencies and city councils is to introduce social policies to create employment opportunities for citizens. With the enhanced quality of life, the financial and emotional wellbeing of businesses and employees are significantly improved. Attempts have been made around the world to improve the quality of life from smart city levels (Mozūriūnaitė & Sabaitytė, 2021). For instance, the Japanese city of Yokohama organizes and supports the local artist community by organizing exhibitions and workshops (Arroub et al., 2016). In the United States, healthcare service campaigns are organized to offer healthcare services to its citizens throughout its states. The Barcelona Smart City Project in Spain is considered to be the smart city implementation to enhance the local economy of the city for its citizens and enhance the quality of life through extensive collaboration between the entire community, citizens, and government (Angelidou, 2016, Angelidou, 2017, March & Ribera-Fumaz, 2016). Another example is the construction of the King Abdullah Economic city, which has been undertaken by Saudi Arabia's government to design a smart city to enhance the quality of life for its residents through high-speed broadband networks aimed at improving services (Moser, Swain & Alkhabbaz, 2015).

3-Urbanization

A distinctive feature of a smart city is urbanization. According to Arroub et al. (2016), urban dwellings are modern utopias that offer their residents a better life through smart city initiatives aimed at reducing the challenges created by rapid urbanization. Urbanization is primarily responsible for causing several challenges affecting citizens and the environment (Wall & Stavropoulos, 2016). These include air pollution, inadequate waste management, traffic congestion, lack of resources, and poor infrastructural developments. Urbanization is also characterized by entrepreneurship, which enhances local and national economies through strong governance, innovative technologies, and collaboration among various stakeholders (Zubizarreta, Seravalli & Arrizabalaga, 2016). According to Eremia, Toma & Sanduleac (2017), smart city initiatives reinforce urbanization-based industrialization and entrepreneurship to support regional development and resolve urban city challenges, enhancing the lives of the citizens in the process through good governance.

4-Smartness

The final characteristic of a smart city, as identified by researchers, is smartness, which uses technological innovations such as artificial intelligence, cloud computing, big data analytics, virtual reality, augmented reality, and 4G and 5G networks to enhance the communal, environmental, and economic aspects of the city (Postránecký & Svítek, 2017, Husar, Ondrejička & Varış, 2017). According to Lara et al. (2016), the smartness of a smart city aims at forming a community that enhances the quality of life for its residents through technological innovations. Yigitcanlar & Kamruzzaman (2018) reported that the smartness of the city is linked to the formation of a smart community where governments, businesses, and citizens collaborate through technological innovations to support urban development.

VI. Smart City Challenges

While a smart city offers opportunities to grow through interconnected concepts and notions, there are several challenges related to its implementation, functioning, and design (Law & Lynch, 2019, Monzon, 2015, Al Sharif & Pokharel, 2022, Khatoun & Zeadally, 2016). The challenges related to the design and functioning of a smart city are the massive amount of data collected through different sensors, networks, and other devices, and privacy issues including sensitive data that can be retrieved by third parties and hackers and maintaining the sustainability of the smart city.

1-Design and Maintenance Challenges

According to Khatoun & Zeadally (2016), designing a realistic smart city is challenging because of the design and maintenance costs. Design costs are linked with the costs needed for starting the smart city, while maintenance cost is linked with its functioning and operationality (Law & Lynch, 2019). Both types of costs can significantly place financial burdens on city councils and municipalities.

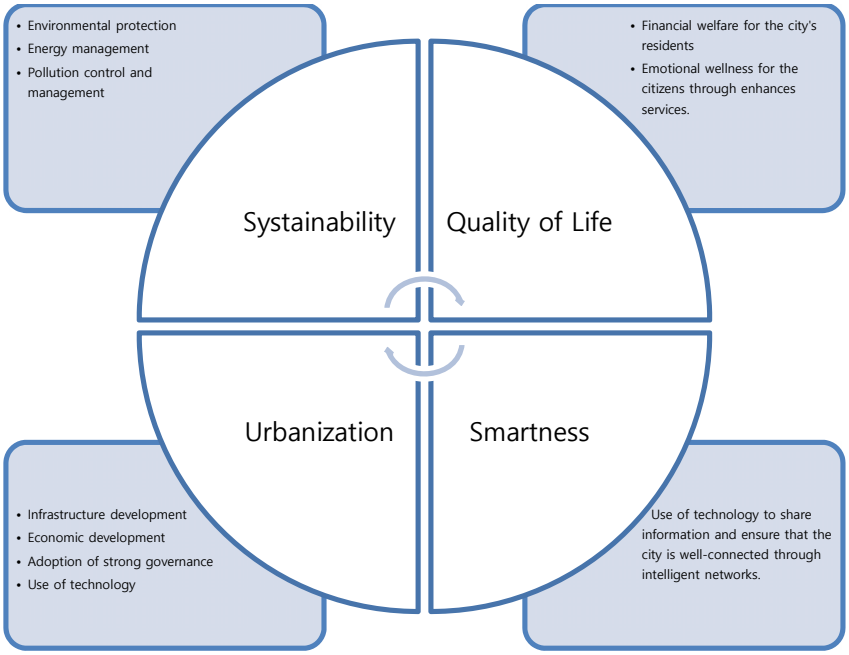

Fig. 3: Characteristics of a smart city

Source:(Yigitcanlar & Kamruzzaman, 2018, Mozūriūnaitė & Sabaitytė, 2021, Zhu, Shen & Ren, 2022, Zubizarreta, Seravalli & Arrizabalaga, 2016, Arroub et al., 2016, Wall & Stavropoulos, 2016, Eremia, Toma & Sanduleac, 2017, Postránecký & Svítek, 2017, Husar, Ondrejička & Varış, 2017)

2-Heterogeneity of Data

Smart cities also face the challenge of data heterogeneity as they comprise several sensors, devices, and networks. Integration of all of these devices is essential to enhance the reliability and functionality of the smart city, which is achieved at the application layer (Al Sharif & Pokharel, 2022). However, incompatibilities among devices can result in difficulties in their integration and operation within the layer. Additionally, universal accessibility in smart cities is challenging since it comprises various hardware and software devices to integrate the heterogenous systems (Law & Lynch, 2019).

3-Privacy and Security

Privacy and security challenges are growing concerns in smart cities as information can be retrieved by hackers and third parties. While smart cities offer enhanced services and better quality of life to their citizens, malicious attacks have also increased with technological developments (Law & Lynch, 2019, Monzon, 2015).

VII. Different Smart Cities in The World

NEOM City, Saudi Arabia:

The story of NEOM city started at the "Future Investment Initiative" conference in Riyadh, Saudi Arabia, on October 24, 2017, when Crown Prince Mohammed bin Salman announced the launch of NEOM city as a destination for dreamers of the future (Doheim et al., 2019). The purpose of the project's promoters is to brand a new city with many innovative development opportunities that will make NEOM an international hub for knowledge, innovation, and trade. To create NEOM, a creative class worldwide has been invited, with promises of a new life in a beautiful place and an independent economic zone with its own regulations, laws, and taxes (Attia et al., 2019). To provide a unique lifestyle for NEOM's residents, today's newest technologies will be implemented in healthcare, growing and processing food, transportation, digital air, net-zero carbon houses, renewable energy, the robots industry, and online education. NEOM city has a strategic location adjacent to the beautiful views of the Gulf of Aqaba, along the Red Sea coastline, and near the Suez Canal involves significant maritime trade routes. It is spanning across three countries: Jordan, Egypt, and Saudi Arabia, which have beautiful weather, charming nature, and a richness of natural resources such as wind speed (an average of 10.3

m/s) and perennial solar resources (20 MJ/m^2) (Doheim et al., 2019). The reason for selecting this location is the plethora of exceptional development potentials that would make NEOM a global hub for trade, knowledge, and innovation. In addition, this location has plenty of mineral resources, gas, and oil. The decision to build NEOM in a new land was based on the idea of creating a new city that does not involve the common characteristics of conventional cities. Everything in it is new: new technology, new regulations, fresh investments, a robotic population, and young people (Attia et al., 2019). This futuristic megacity is divided into four regions: Sindalah, The Line, Trojena, and Oxagon, and each region has it is a special role in development (Figs. 3 & 4). Saudi Arabia plans to start construction in 2017 and complete the first phase of NEOM by 2025. "It's an attempt to do something that's never been done before, and it's coming at a time when the world needs fresh thinking and new solutions. Simply put, NEOM will be a destination, a home for people who dream big and want to be part of building a new model for sustainable living, working and prospering" (NEOM Official Website, 2022).

Fig.3. Oxagon Region

Source: NEOM Official Website, 2022

Fig.4. The Line Region

Source: NEOM Official Website, 2022

Nice City, France:

Nice in France is a vital European smart city, which worked with Cisco to get potential advantages of the Internet of Everything (IoE). Moreover, this task provided four primary administrations to the city: smart transportation, smart environment sensing, smart waste management, and smart lighting. The city of Nice started using NFC technology to execute payment operations in transport, cable car, shops, exhibitions, and so on (Pathak & Pandey, 2021).

Another important part of Nice is the grid demonstration project. This project makes a smart sunlight-based neighborhood in city regions by meeting thermal storage, solar power generation forecasts, disseminated power, and load administration. Smart energy is considered the primary element of Nice, among other smart city elements (Pathak & Pandey, 2021).

London City, United Kingdom:

According to IESE Business School University of Navarra (2016), London is one of the top smart cities in the world due to many smart practices. One of the substantial technologies is the London Information Store, which is considered the main stage that allows open information to be available in multiple applications development. This city is famous for its transportation frameworks, remarkable traveler administration, and digital cash to increase proficiency in investment funds. Furthermore, it involves other smart technologies, such as smart energy, smart human services, and smart network (IESE Business School University of Navarra, 2016).

San Francisco, United States of America:

San Francisco (SF) depends on innovation to expand the transportation framework, improve the operational execution of structures, reduce energy utilization, and concentrate waste administration methodology. SF combines smart energy, smart network, and smart transportation as its primary segments that serve residents (Pathak & Pandey, 2021). SF City transportation organization has launched the vision of shared, electric, connected, and automated vehicles (SECAV) to supplant single-tenant vehicles. Therefore, this vision has resolved the issues caused by the time-consuming and costly transportation framework within city suburb. Moreover, SF provides online instruments to build openness for soil reusing and treatment. Another fundamental smart component of SF is that 41% of urban vitality requests are fulfilled by sustainable power sources. Multiple advanced waste management methodologies are used to maintain the title of "greenest city" (Pathak & Pandey, 2021).

VIII. Conclusion

This work provided a concise overview of the definitions, characteristics, dimensions and challenges related to the concept of a smart city. The smart city concept is significantly growing with the massive amount of literature available to enhance the quality of life for citizens and organizations while creating employment opportunities. Furthermore, the smart city notion is also based on sustainability, which focuses on protecting natural resources for future generations and serves as a guide to implement measures to protect the environment from degradation by human activities. It is also significant in managing problems caused by urbanization, such as traffic congestion, increased crime rates, pollution, water scarcity, food shortages, and inadequate housing facilities. While it provides opportunities for cities to grow, it also comes with challenges that can hinder its progress, such as privacy and security challenges, high maintenance and design costs, and data heterogeneity. Nevertheless, governmental institutions, private firms, nongovernmental agencies, and citizens can collaborate to successfully create smart cities.

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