International Journal of Future Engineering Innovations

Smart Cities: Technologies and Components

Matthew NO Sadiku [1*], David Padi [2], Janet O Sadiku [3]
[1] Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX 77446, USA
[2] Alumnus, Graduate School of International Business and Leadership, Midwest University, Wentzville, Missouri, USA
[3]Juliana King University, Houston, TX, USA

* Corresponding Author: **Matthew NO Sadiku**

Article Info

ISSN (online): 3049-1215
Impact Factor (RSIF): 8.25
Volume: 03
Issue: 04
Received: 03-05-2026
Accepted: 02-06-2026
Published: 01-07-2026
Page No: 29-38

Abstract
The rapid growth of global urbanization has created an urgent need for innovative urban management solutions. The concept of a "smart city" has emerged as a forward-thinking approach to addressing the complex challenges of urban life. A smart city is an urban area that uses data collection and technology to enhance sustainability and efficiency in city operations while improving the quality of life for its residents. Smart cities represent a new trend focused on leveraging digital technology to create better living conditions. In these cities, information and communication technology (ICT) is integrated with traditional infrastructure. They are envisioned as ideal urban environments in which various aspects of a city, including the economy, education, energy, environment, transportation, tourism, and governance, are managed effectively. The ultimate goal of a smart city is to enhance the quality of life for its residents. This paper examines the enabling technologies and foundational components that make up smart cities.

DOI: https://doi.org/10.54660/IJFEI.2026.3.4.29-38

Keywords: smart cities, enabling technologies, components, urbanization

1. Introduction

Historically, cities have functioned as epicenters of innovation and economic growth. Today, more than half of the world's population lives in cities, and this number is expected to increase. Cities consume nearly three-quarters of the world's natural resources and generate a similar proportion of pollution and waste. As urban populations grow, cities are becoming larger, more sophisticated, and increasingly important to global economic and social life. According to the United Nations, the global urban population has grown significantly, with projections indicating that by 2050, 68% of the world's population will reside in urban centers. Consequently, cities face the challenge of doing more with fewer resources in both developed and developing nations. They are undergoing digital transformations to enhance environmental, financial, and social aspects of urban living. As a fundamental responsibility, every city must provide its citizens with essential services such as housing, food, water, energy, jobs, healthcare, education, transportation, and security. The demand for these services stretches cities' infrastructure to its limits as populations grow. Modern cities are vast communities, often with millions of residents. They serve as the world's economic engines, generating significant opportunities. Cities bring people together and facilitate the exchange of information among diverse cultures and skill sets. They cooperate, compete, and evolve alongside one another. As people adapt to city life, cities, in turn, are transformed by their inhabitants. Cities offer opportunities for employment, economic development, and improved living standards, which often drives migration from rural areas to urban centers. Both developed and developing nations are under pressure to enhance their urban environments by addressing large-scale challenges associated with rapid urbanization. As a response, smart city technologies are being implemented. A smart city is an urban area where technology and data collection work together to improve quality of life, promote sustainability, and increase operational efficiency.

2. Methodology

The study employed a qualitative research method combined with a literature review. This approach was effective in examining the relationship between smart city implementation and the adoption of related technologies and social practices. It offered valuable insights into how smart cities connect people, information, and technologies to create efficiencies, improve sustainability, drive economic development, and enhance the quality of life for residents and workers in the city. This research enables policymakers and organizations to implement environmental strategies that address urbanization, global warming, sustainable development, and resource scarcity. To gather data, the researchers drew from multiple sources, including peer-reviewed scholarly journals and other relevant materials.

3. Concept of Smart Cities

The concept of smart cities emerges as a major response to the increasing global urbanization, global warming, sustainable growth, scarcity of resources, and socio-economic challenges faced by cities worldwide. IBM's Smarter Cities work began in late 2008 as part of the Smarter Planet initiative. The idea of "smart city" first appeared in the 1990s, with focus on the impact of ICT on modern infrastructures within cities. It is the merge of some other more familiar urban policies such as digital city, green city, knowledge city.

The word "smart" can be used to describe any device that can process information and can communicate with something. The term "smart cities" is a fuzzy concept and there is not a one-size-fits-all definition of the concept. The term has gained traction across sectors and has pervaded the fields of sustainability, urban planning, architecture, engineering, and computer science.

As typically shown in Figure 2 [6], a smart city is a high-tech urban area that connects people, information and technologies in order to increase life quality. It integrates ICT in a secure manner so as to manage the city's assets, increase operational efficiency, share information with the public, and improve citizen welfare. ICT is the key technology that weaves digital intelligence into cities' fabric. The main motivation for using ICT is the desire to eradicate human error. Smart cities are those communities that pursue sustainable economic development through investments in human and social capital and manage natural resources through participatory policies.

The main target for developing smart cities is to provide the following services depicted in table 1 [7]:

Table 1: The Main Target for Developing Smart Cities

No.	Description
1	Convenience of the public services
2	Delicacy of city management
3	Livable and sustainable living environment
4	Smartness of infrastructures
5	Effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens.
6	Adequate water supply and electricity supply
7	Sanitation, including solid waste management
8	Efficient urban mobility and public transport
9	Affordable housing, especially for the poor
10	Good governance, especially e-Governance and citizen participation
11	Safety and security of citizens, particularly women, children and the elderly
12	Health and education

4. The Characteristics of Smart Cities

Characteristics that may be used to determine a city's smartness include [8]:

- A technology-based infrastructure, which includes a critical mass of smartphones, sensors connected by high-speed communication networks, and ICT. A sensor converts parameters of a physical nature to an electronic signal.
- Environmental initiatives, e.g. green rooftops towards clean and green environment
- A functioning public transportation system
- Citizen engagement, humans living, and working in the city and utilizing its resources
- Open government and citizen-centric governance, bridging gaps between citizen and administration

A smart city uses networking and computing technologies to create efficiencies, improve sustainability, create economic development, and enhance quality of life for those living and working in the city. It connects various items such as street lighting, smart buildings/homes, smart factories, smart hospitals, smart mobility, urban manufacturing, and urban farming [9]. It monitors the conditions and integrates critical infrastructures such as bridges, tunnels, roads, subways, airports, seaports, and buildings. Components of a smart city include smart people, smart governance, smart homes, smart infrastructure, smart technology, smart campus, smart economy, smart water, smart living, smart factory, smart health, smart parking, smart shopping, smart transportation, and smart environment [2].

The Institute of Electrical and Electronics Engineers (IEEE) define a smart city as a city that brings together technology, government, and citizens to enable the following characteristics: smart economy, smart mobility, smart environment, smart people, smart living, and smart governance [10]. The six major characteristics are briefly explained as follows [10-12].

Smart People in a smart city emphasizes the importance of citizens, who are the city's most valuable resource. Smart city initiatives should create an urban environment that supports a high quality of life for residents. Residents' attitudes toward smart city technologies strongly influence whether those technologies are accepted and used. The idea of smart people includes qualities such as lifelong learning, social and ethnic diversity, flexibility, creativity, open-mindedness, and active participation in public life.

Smart Living focuses on improving the quality of urban life for all stakeholders. A key goal of smart cities is to make daily routines more efficient and convenient. Experts suggest that smart cities can be more efficient and enjoyable places to live. By using digital technologies, smart cities improve the efficiency and effectiveness of city services while enhancing the livability of urban areas.

Smart Mobility is closely connected to people's daily lives. It aims to reduce congestion and support faster, greener, and more affordable transportation options. The main purpose of smart mobility is to connect a city's resources, including people, goods, and information. Through technology, smart mobility helps people plan travel, use public transportation more effectively, reduce road traffic congestion, and promote environmentally friendly transportation. *Smart Economy* refers to e-business, e-commerce, and broader economic opportunities. It focuses on competitiveness and economic growth through innovation, productivity, entrepreneurship, and a flexible labor market. *Smart Environment* involves the efficient use of energy and natural resources. It includes smart energy, renewable energy sources, water management, waste management, drainage systems, and public lighting. The smart city concept suggests that urban environments are becoming more intelligent and sustainable. *Smart Governance* refers to the use of information and communication technologies to improve public services and democratic processes. City governments provide essential services that support modern life, and smart governance helps ensure that the interests of all citizens are considered. It also encourages citizen participation in decision-making through ICT-based solutions and e-government services.

These six components are illustrated in Figure 3 [13].

5. The Smart City Enabling Technologies

The efficacy of a smart city is inextricably linked to its technological backbone. These enabling technologies converge to collect, transmit, and analyze vast quantities of data, facilitating informed decision-making and automated responses. Smart technologies are the key for the design, implementation, and operation of smart cities. Smart cities use smart technologies (such as IoT, WSN, and CPS) to improve the quality of life of the residents. They apply a wide range of electronic and digital technologies that enable its devices to communicate. Enabling technologies include the following [11,14-19]:

5.1. Internet of Things (IoT)

The Internet of Things (IoT) is perhaps the most critical enabling technology of a smart city. IoT refers to a network of physical devices, vehicles, appliances, and infrastructure embedded with sensors, software, and connectivity that allows them to collect and exchange data. These "smart objects" form a sensory network across the city. For example, IoT sensors can monitor air quality, track public transit vehicles in real-time, or detect water leaks in municipal pipelines. The IoT is the network of interconnected devices (called things) including computers, smartphones, sensors, buildings, structures, vehicles, actuators, and wearable devices. It has four components: the things, the local area network, the Internet, and the cloud. Sensors play an important role to make cities better, safer, efficient and sustainable. As shown in Figure 4, the IoT is the technical backbone of smart cities [16].

5.2. Artificial Intelligence (AI)

While IoT provides sensory input, artificial intelligence (AI) and machine learning (ML) serve as the analytical brain of the smart city. AI algorithms process the massive datasets generated by IoT sensors to identify patterns, optimize systems, and predict future events. In urban planning, AI can optimize waste collection routes to reduce emissions or manage traffic signals dynamically based on real-time congestion data.

5.3. Cloud Computing

Technologies like edge computing and hybrid cloud architecture enable real-time data analysis. This feature enhances the responsiveness of city services by decentralizing data storage and computation closer to the source. Moreover, cloud platforms integrate with AI and IoT networks, allowing cities to collect, analyze, and respond to data from sensors, traffic systems, and public utilities. These cloud-based solutions also strengthen cybersecurity by employing advanced encryption methods and decentralized access controls to protect sensitive information.

5.4. Edge Computing

The storage and processing of urban data rely heavily on cloud computing, which provides scalable and centralized data management. However, to reduce latency and bandwidth usage, edge computing is increasingly deployed. Edge computing processes data closer to its source (e.g., at the sensor level), ensuring that only essential information is transmitted over the network, which is crucial for applications requiring immediate action, such as autonomous vehicle navigation. Figure 5 shows edge computing in smart cities [20].

5.5. Big Data

To provide all the necessary services to the residents of smart cities, the IoT technology generates big data (BD). Most smart city applications, such transportation systems, energy management, water utility, waste management, healthcare systems, and surveillance (with cameras) systems, generate big data. The large quantity of data generated by thousands of sensors and devices in a smart city creates a big data. The BD refers to a group of large data sets that would be hard to process using traditional data processing. It is a high-volume, high-velocity, and high-variety information that requires special information processing tools. Gigabit networks will allow smart cites to collect and analyze big data.

5.6. Blockchain

Blockchain technologies promise to help by improving cybersecurity as well as user's privacy. Blockchain can contribute to reducing these security gaps. It is a platform on which the massive data derived from smart cities can be safely stored and accessed by those who are authorized to access it.

5.7. Digital Twin

A transformative trend shaping the future of urban planning is the deployment of city-scale digital twins. A digital twin is a highly detailed, dynamic virtual replica of a physical city. It integrates real-time data from IoT sensors to simulate urban environments. This technology allows urban planners and government officials to test scenarios, model the impact of

new infrastructure, and optimize emergency response strategies before implementing them in the real world.
Other smart city technologies include dashboards, firewalls, machine learning, SCADA systems, and nanotechnology.

6. Performance Measurement of Smart City

Measuring the performance of a city as a smart city is a challenging task. The following measurement system identifies six layers and levels of a smart city:
Layer 0: The City Layer. Smart cities must begin with the concept of the city itself, rather than focusing solely on being "smart." This layer represents the traditional components found in every city.
Layer 1: The Green City Layer. This layer is inspired by new urbanization theories, particularly those promoted by LEED initiatives.
Layer 2: The Interconnection Layer. Integral to the smart city concept, this layer refers not only to "infrastructural green islands" but also to the city-wide promotion of green economies.
Layer 3: The Instrumentation Layer. This layer includes real-time connection outlets such as radiofrequency transmitters, traffic signals, smart meters, infrastructure sensors, and traffic sensors.
Layer 4: The Open Integration Layer. Smart city applications should be capable of intercommunicating and sharing data, content, and services.
Layer 5: The Application Layer. As cities become more technologically empowered, the core systems on which they are built become interconnected.
Layer 6: The Innovation Layer. Smart cities foster an environment that encourages innovation and creates new business opportunities. Additional measures of the "smartness" of smart cities can be found in the original reference.

7. Overview of Global Smart Cities

Smart cities around the world are diverse in their characteristics. Smart cities are now a regularly appearing phenomenon of urban design across the world. Countries like the United States, China, India, UK, Japan, Canada, etc. have started developing smart cities for the future while modifying the existing cities to make them smarter. Many cities
across the globe have jumped into the smart city bandwagon. They have started transformational projects called smart city initiatives to better serve citizens and to improve their quality of life. There is no universal panacea that can turn a city into a smart city. Instead, several initiatives all over the world have been launched to transform towns or cities from scratch to smart cities. For example, India decided to set 100 smart cities in May 2014. South Korea initiated 47 U-City (Ubiquitous City) projects in May 2013.
So far no city has fully become a smart city. However, several cities are actively pursuing smart city strategy. A few of them stand out as the furthest ahead in development. These mega cities include:
Singapore, for example, is the smartest city in the world. People who live there or visit often feel a sense of sentimentality, as if they are living in the future. In the late 1980s, Singapore advertised itself as the "Intelligent Island." The city is exemplified by the Smart Nation plan, which has effectively made this nation-state a testbed for the use of the Internet of Things to improve city life. Singapore has a masterplan for community-focused health. Its Housing and Development Board (HDB) provides all citizens with access to free public housing [22].
London is the UK capital, came second to Singapore. The Smart London Board shapes the vision for London's smart cities agenda and investment in data infrastructure. It advises the mayor on implementing new digital technologies across London's infrastructure, utilities, and public services. This ambition is matched by the city's voracious appetite to be the leader of everything nationally and internationally [23].
Barcelona is the third smartest city. It is well known for its leadership in innovative planning. At the international level, Barcelona was recognized for its accessible open spaces and pedestrian-friendly infrastructure. The fundamental principle of modern urban planning policy in Barcelona is to create a more efficient city while respecting the interests of local residents. In 2013, the city recognized the importance of developing a clear smart-city strategy and demonstrated its readiness to become Spain's first high-tech city [24].
In 2013, Amsterdam sought to expand its 11 existing air quality measurement stations. Then in 2015, the Amsterdam Smart Citizens Lab was established. Here, citizens, social institutions, research institutions, and the central government have joined hands to gain deeper insight into the environment, identify problems, and develop future solutions. Citizens' questions, concerns, and input are central to this initiative [25].
Tokyo is also one of the largest cities in the world by population. The key principles of urban planning in Tokyo are based on security, energy efficiency, and pollution control. The city uses intelligent systems of training specialists to prevent the consequences of natural disasters. A distinctive feature of urban planning in Tokyo is the emphasis on improving citizens' safety due to frequent natural disasters [26]. Figure 6 shows the city of Tokyo [27].
New York City reached ten million for the first time in the mid-20th century, New York being the first. A program that started in 2013 is running, aiming to produce methane from food waste in the city. New York is a member of the C40 group, consisting of 58 large cities from around the world. To be a member of the group, a city must be committed to implementing sustainable climate-related measures [28].
Los Angeles has a technologically proactive city government. Since 2013, Los Angeles has progressed from being a moderate digital status to a leading digital city. Among other things, the city has a web-based system to inform the citizens about city services [11].
Chicago has strongly embraced smart city principles. The city wants to become "the most data-driven government in the world." In 2012, the mayor signed the city's open data policy. It created an open data platform and mandated cross-functional collaboration. The city embarked on sensor projects such as the Array of Things, which aims to collect and disseminate real-time data. Engineers, scientists, policymakers, and residents collaborate to make Chicago healthier, smarter, more livable, and more efficient [29].
New Delhi is in the initial planning stages of its smart cities initiative, which is part of the broader overarching goal of India's smart cities program. The city is following the lead of the nation's existing environmental and land-pooling policies [29].
Other smart mega cities include Philadelphia, Paris, Ottawa, Toronto, Manchester, Melbourne, Seoul, Dubai, Hong Kong, and Beijing. These smart mega city forerunners are setting a trend for others to follow.

7.1. Smart City Components

Smart technologies help cities sustain growth and improve efficiency for both citizen welfare and government. They can also deliver a better quality of life. Key conceptual components of smart city can be grouped into three categories of core factors: technology (infrastructures of hardware and software), people (creativity, diversity, and education), and institution (governance and policy). Smart city technologies are applicable in the urban domain: economy, mobility, security, education, living, and environment

Smart buildings and homes are integral components of smart city projects. These buildings consume significant amounts of materials, energy, and water, and they have a wide-ranging impact on both human health and the environment. By attaching sensors to buildings, we can detect wear and tears and monitor their structural health. Smart appliances, such as intelligent fridges and home security systems, enable more efficient living. Smart energy management and grids are essential for sustainable urban development. Smart grids use digital technology to monitor and manage electricity transmission, integrate renewable energy sources, and implement demand-response strategies to balance supply and demand. At a micro level, smart buildings utilize IoT sensors to monitor occupancy and environmental conditions, automatically adjusting lighting, heating, and cooling systems to minimize energy waste. Moreover, smart transportation is crucial, as traffic congestion poses significant challenges for daily commuters in urban areas. It ensures that public transportation meets user demand and incorporates smart mobility applications, which can reduce commuting time. The role of smart mobility is to connect the city's resources: people, goods, and information. The evolution of autonomous and electric vehicles further influences transportation systems. Smart parking addresses the challenge of finding available parking spaces in major cities by helping drivers locate them without aimlessly circling crowded blocks. Additionally, smart lighting uses predictive analytics to replace streetlights before they fail and sets automated workflows to minimize downtime when replacing lights. Smart water management aims to tackle challenges in urban water management by employing ICT solutions and systems. It includes a smart water metering system that allows utilities to monitor and record water quality and consumption. Smart waste management addresses the increasing waste generated by urbanization. It encompasses the collection, transport, recycling, and disposal of waste, focusing on improving the efficiency of these processes, including collection, separation, reuse, and recycling. A smart university adopts digital technologies broadly, enhancing the teaching and learning process. It comprises five key entities: smart people, smart buildings, a smart environment, smart governance, and a knowledge grid. The benefits of a smart university include reduced electricity consumption, a conducive social environment, easy reporting of irregularities, convenient location tracking of people on campus, enhanced theft prevention, and efficient maintenance of attendance records. Students can create their own online learning activities while parents can support their child's learning from home. Today, all universities provide on-campus Wi-Fi, which students frequently use to connect to the Internet.

7.2. Smart City Applications and Solutions

Smart city solutions are transforming how we move, eat, and stay safe in urban environments. By integrating AI, IoT, and sustainable technologies, cities can become more efficient, responsive, and environmentally friendly. These innovations improve daily life while reducing emissions, energy consumption, and response times. Common applications include [32,33]:

- **Autonomous Vehicles:** Autonomous vehicles will transform mobility. Self-driving shuttles and coordinated platoons reduce road congestion by up to 40%. Electric fleets lower emissions, improving air quality and energy efficiency across urban streets. In San Francisco, Waymo is already available. Trust and comfort are the primary benefits of the services being delivered today. However, autonomous travel systems require infrastructure that is not yet ready. Cities need improved energy distribution and traffic management (for air, sea, and land) to offer these services to their citizens.
- **Air Taxis:** As smart city technologies evolve, the adoption of air taxis is expected to increase significantly in urban areas. Apart from supporting urban development and the reduction of road congestion, these advanced air mobility solutions can drastically reduce the time required to transport medical supplies, organs for transplant and healthcare professionals to and from isolated areas.
- **Rooftop Farming:** Localized food production provides up to 20% of neighborhood produce. Precision agriculture minimizes food miles and reduces carbon footprints while promoting fresh, sustainable diets.
- **Public Safety Systems:** Facial recognition, anomaly detection, and drone integration improve monitoring and emergency responses. Response times drop by 60% compared to traditional patrols, enhancing citizen safety.
- **Adaptive Street Management:** Smart city technology enables responsive waste management, adaptive street lighting, and flexible zoning policies. Resources are used more efficiently, improving comfort and sustainability in urban areas.
- **Renewable Energy:** Renewable energy technologies, including solar panels and wind turbines, are increasingly being integrated into urban environments to generate clean power and reduce reliance on fossil fuels. Advanced energy storage systems, including next-generation batteries, enable cities to store surplus energy and balance supply during peak demand. Additionally, smart grids equipped with real-time monitoring and management tools optimize energy distribution, ensuring efficient and sustainable power use.
- **Smart Lighting:** IoT-powered smart lighting systems use connected sensors to adjust street lighting based on actual activity levels. This enhances energy efficiency and improves public safety by responding to environmental changes or emergencies.
- **Smart Parking:** The service likely to become increasingly common in urban areas as smart city technologies evolve is smart parking systems. These systems use sensors, cameras, and data analytics to provide real-time information on parking space

availability. Drivers can use mobile apps to find and reserve available parking spots, reducing the time spent searching for parking and decreasing traffic congestion.

- **Public Safety:** IoT enhances public safety by integrating sensors, cameras, and communication networks. These systems detect incidents, monitor environments in real-time, and facilitate rapid emergency response to ensure proactive protection in urban spaces.
- **Intelligent Traffic Management:** As our cities become smarter, we will start seeing more intelligent traffic management systems. These systems use real-time data and advanced technology to improve traffic flows, reduce congestion and make public transportation more efficient.
- **Intelligent Waste Management:** Intelligent waste management will soon be common in urban areas. These systems use IoT sensors and AI to monitor waste levels, optimize collection routes and enhance recycling. This reduces fuel consumption, lowers carbon emissions and minimizes landfill use. Efficient sorting and predictive maintenance improve recycling rates and resource conservation, contributing to urban sustainability and environmental protection.

8. Future of Smart Cities

The term "smart city" was first used in the 1990s, and since then, three different generations of smart cities have emerged [9]: (1) Smart City 1.0, which was led by technology providers; (2) Smart City 2.0, led by city authorities; and (3) Smart City 3.0, where neither technology providers nor city leaders take full control—instead, a citizen co-creation model is being embraced. Smart cities and the technologies associated with them are constantly evolving. Major companies such as IBM, Cisco, Microsoft, Philips, and Oracle are promoting their products in response to the opportunities presented by cities, which they see as the next significant wave of product development in today's interconnected world. The smart cities of the future will engage all stakeholders—governments, citizens, visitors, and businesses—creating an intelligent and collaborative ecosystem. As cities become "smart," they are also in a state of constant change. These cities represent the future of humanity, requiring our solutions to evolve in tandem. IBM's prominent campaign on smart cities acknowledges the pressure for these urban areas to enhance their intelligence. The effectiveness of a smart city is reflected in how well it utilizes data and technology. As cities grow smarter, they become more livable and responsive. Smart city applications need to align with the aspirations of the city and its citizens [31]. Looking ahead, cities must strive to be greener, focusing on sustainability. The major benefits of green cities include improved air quality through oxygenation and purification, mitigation of the urban heat island effect, increased biodiversity by creating semi-natural habitats, and the incorporation of bio-architecture to bridge the connection between humans and nature through landscape improvements. These factors also positively impact the psychological well-being of residents [34]. As we develop smart cities, we must be intentional and ensure that the cities of the future are inclusive for everyone. Visionary leadership is critical in avoiding potential pitfalls and establishing mechanisms for shared governance. The successful deployment of smart city technologies hinges on the quality of decisions made and the manner in which they are implemented. As smart technology continues to evolve, forward-thinking urban centers are introducing a variety of innovative services and conveniences, earning them the designation of "smart cities."

9. Findings of Benefits and Challenges of Smart Cities

9.1. Benefits of Smart Cities

Smart cities are essentially tech-savvy towns that utilize digital technologies to do their business and create efficient and livable environment. There are many benefits that result from transforming a city into a smart one. They enable social, environmental, economic, and cultural development. They also have the enormous potential to drive the digital economy forward in the coming years. Other benefits include the following [18]:

Citizen engagement is essential to the smart city concept. The primary focus of any smart city should be its people, aiming to provide benefits such as improved quality of life for residents and visitors, enhanced economic competitiveness to attract talent, and sustainability. Smart cities should foster a positive community by connecting people with their environment, promoting citizen participation and empowerment. They are dynamic places to live and serve as breeding grounds for new ideas. Government engagement is another important factor in the success of smart cities. Effective governance is crucial for implementing smart city initiatives, which aim to improve governance and enhance the quality of life for citizens. Smart cities offer numerous benefits for both government and citizens, including effective service provision, enhanced quality of life, and improved security. They enable smarter decision-making and harness the collective intelligence of the city's residents. Many smart cities around the world are beginning to promote small and medium-sized enterprises (SMEs) and social enterprises. Government can utilize data-driven policymaking for targeted interventions, providing measurable evidence of effectiveness. Environmental sustainability is a critical goal for smart cities. In alignment with the United Nations Sustainable Development Goals (UN SDGs), sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." One of the pressing objectives for smart cities is to reduce their environmental footprint. Smart technologies allow for precise monitoring and management of resources, significantly lowering waste and emissions. Energy-efficient smart buildings, equipped with automated climate control and lighting systems, can drastically reduce electricity consumption. Moreover, smart cities are better prepared to address the impacts of climate change. Real-time environmental monitoring enables early detection of peaks in air pollution and predictions of extreme weather events, facilitating swift emergency responses and mitigating disaster risks. Enhancing public health is vital for benefiting society. The integration of technology in urban planning has profound implications for public health. "Smart health communities" utilize interoperable data systems across healthcare, social services, and environmental monitoring to address the social determinants of health. For instance, deploying air quality sensors helps cities identify pollution hotspots and implement traffic restrictions to protect residents from respiratory illnesses. Economic development plays a key role in smart city initiatives, which serve as powerful engines for economic growth. The global smart city

market is projected to exceed $1,024 billion by 2027, reflecting substantial investments in urban innovation. These investments create a multiplier effect, attracting businesses and talent by providing superior infrastructure, reliable digital connectivity, and a high quality of life. Operational efficiency is another significant economic benefit. Smart water management systems use sensors to instantly detect pipeline leaks, preventing the loss of millions of gallons of water and saving municipalities significant repair costs. Similarly, predictive maintenance of infrastructure—using sensors to monitor the structural integrity of bridges and roads—allows cities to address wear and tear before catastrophic failures occur, safeguarding both finances and lives. Improving citizen engagement is a defining characteristic of successful smart cities, which prioritize the citizen experience. Modern governance requires transparency and accessibility. By providing open data platforms, mobile applications, and digital service portals, smart cities foster closer relationships between the government and its residents. Citizens can easily pay utility bills, report potholes, track public transit in real-time, and participate in civic decision-making processes. Cities like Amsterdam and Barcelona have pioneered the “living laboratory” concept, where citizens, private companies, and academic institutions collaborate to co-design and test urban solutions in real-world settings. This participatory approach ensures that technological implementations align with the community's actual needs, promoting digital equity and social inclusion.

9.2. Challenges of Smart Cities

Despite the numerous benefits, the transition to smart cities presents significant challenges. Current efforts to develop these cities face several obstacles, including extreme weather conditions, growing food shortages, competition for resources, rising rural-to-urban migration, increased congestion, an aging population, and higher public service costs [35]. While rapid advancements in information and communication technology (ICT) facilitate the digitalization of cities, they also introduce new challenges due to the increasing complexity and dynamics within smart cities. The development of smart cities comes with potential barriers and other challenges, which include the following [18,36]:

Data privacy is a significant concern for smart cities, which rely heavily on the constant collection and analysis of data that creates detailed digital footprints of residents' daily lives. Technologies like facial recognition, smart meters, and traffic sensors gather vast amounts of personal information. This extensive data collection raises crucial privacy issues regarding who has access to the data, how it is used, and how it is protected. The potential for government surveillance or corporate misuse of personal data highlights the need for stringent data governance policies and the implementation of “privacy by design” principles. Cybersecurity is another major concern; as cities become increasingly digitized, they become more susceptible to cyberattacks. A breach in a smart city's network could incapacitate critical infrastructure, such as power grids and traffic control systems, posing severe risks to public safety. Additionally, the widespread collection of data through surveillance and sensors raises significant privacy concerns that require robust data protection governance to prevent the emergence of totalitarian surveillance systems.

The digital divide also poses a substantial limitation. While smart cities promise improved services, there is a significant risk that they may exacerbate existing inequalities. The “digital divide” refers to the gap in access to digital technologies and digital literacy, which can prevent marginalized communities from benefiting from smart city innovations. It is crucial that the deployment of smart technologies is equitable; otherwise, there is a persistent risk that the benefits of smart cities will disproportionately favor affluent neighborhoods. Ensuring that all communities have access to high-speed internet and digital services is a critical challenge for urban planners. Interoperability presents a fundamental technical hurdle in implementing smart cities across diverse systems. Modern smart city projects typically integrate 10 to 12 advanced technologies, such as AI surveillance, smart lighting, and real-time analytics platforms. These systems, often developed by different vendors, must communicate seamlessly to function effectively. The lack of standardized communication protocols and data formats commonly results in fragmented "silos" of information, which diminishes the overall efficiency of the smart city ecosystem. Legacy infrastructure limits the integration of cutting-edge digital systems with aging physical infrastructure, creating a significant barrier. Many cities still depend on outdated water, transportation, and energy systems that are nearing the end of their useful lives due to decades of underinvestment. Retrofitting these old systems with modern sensors and connectivity is not only technically challenging but also highly disruptive. Moreover, public procurement processes are often biased toward traditional "pieces-and-parts" approaches rather than holistic, resilient solutions, complicating modernization efforts. Financial constraints are another critical factor. Funding smart city projects presents a major barrier, especially for developing economies and mid-sized cities. The technological complexity and scale of these initiatives require substantial capital investment. Local governments often lack sufficient funds and must rely on Public-Private Partnerships (PPPs) to bridge the funding gap. However, PPPs come with their own complexities, including risk-sharing, governance structures, and the potential prioritization of corporate profits over public values. Finally, the lack of standardization prevents the realization of the full benefits of the Internet of Things (IoT). IoT requires a standard platform and a "battle-tested" framework for the next generation of smart cities. International standardization plays a crucial role in ensuring interoperability among services and devices, with standards established by organizations such as ISO and IEEE guiding the development of smart cities.

10. Conclusions

Cities are seen as crucial to the future, with smart cities representing a significant evolution in urban living. These smart cities rely heavily on advanced computing technologies applied to essential infrastructure and services. As cities are increasingly asked to do more with less, there is an urgent need to enhance their suitability, efficiency, sustainability, and safety. This demand is driving numerous initiatives worldwide, prompting cities to pursue smart city projects. The primary goal of a smart city is to improve the quality of life for its residents by providing a sustainable environment at affordable costs.

This concept aligns with the democratization of technology. By promoting collaborative governance, prioritizing public values, and involving citizens in the design process, urban leaders can create smart cities that are not only technologically advanced but also resilient, inclusive, and sustainable. Currently, smart cities around the globe are in a state of transition. Major high-tech companies are actively supporting these transformations. Local governments now face the challenge of evolving into smart cities and must choose transformation strategies that align with their ambitions. Making cities smarter remains a key priority. Several organizations are fostering smart city development. The Smart City Movement (cma.org/articles/smart-city-movement) is gaining traction internationally. Founded in 1914, the International City/County Management Association (ICMA) aims to be the leading professional association dedicated to creating and supporting thriving communities worldwide. This movement has attracted many technology innovators. The Smart Building Alliance (SBA), established in France in 2012, primarily supports stakeholders in the building industry regarding digital technology. For more information about smart cities, one should consult books in references [3]7-4[6] and related journals:

- Cities
- Journal of Urban Technology
- IET Smart Cities.

Fig 1: A typical city [4].

Fig 2: A typical smart city [6].

Fig 3: The six major characteristics of a smart city [13].

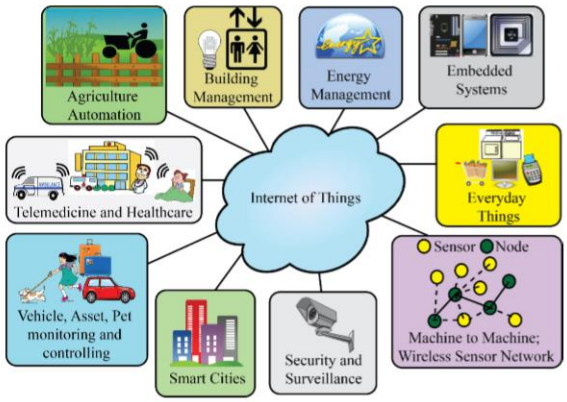

Fig 4: Internet of Things (IoT) in smart cities [16].

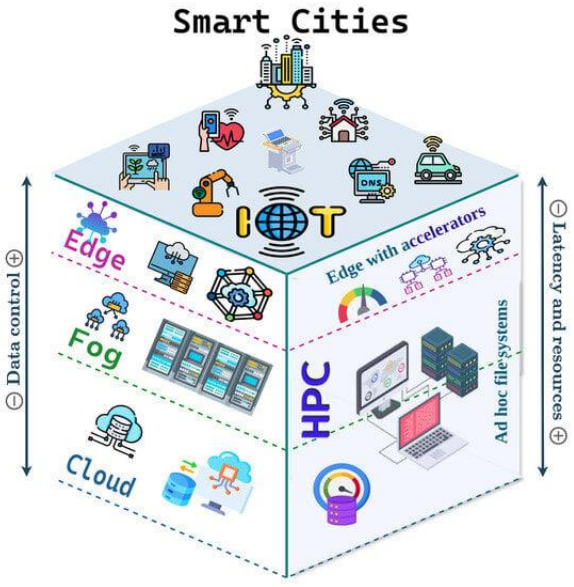

Fig 5: Edge computing in smart cities [20].

Fig 6: The city of Tokyo [27].

Fig 7: Some components of smart cities [12].

References

1. Albino V, Berardi U, Dangelico RM. Smart cities: Definitions, dimensions, performance, and initiatives. J Urban Technol. 2015;22(1):3-21.
2. Sadiku MNO. Emerging Internet-based Technologies. Boca Raton (FL): CRC Press; 2019. p. 17-22.
3. Sadiku MNO, Shadare AE, Dada E, Musa SM. Smart cities. Int J Sci Eng Appl Sci. 2016;2(10):41-44.
4. Locke J. IoT Smart City Applications (2025). Digi International. 2025 May 8 [cited 2026 Jul 1[3]]. Available from: https://www.digi.com/blog/post/iot-smart-city-applications
5. Hayat P. Smart cities: A global perspective. India Q. 2016;72(2):177-191.
6. Ribera Solutions. Smart City, IoT and AI [Internet]. 2025 Jan 16 [cited 2026 Jul 1[3]]. Available from: https://www.riberasolutions.com
7. ISO/IEC JTC 1. Smart Cities: Preliminary Report 2014. Geneva (Switzerland): International Organization for Standardization and International Electrotechnical Commission; 2014.
8. Rouse M. Smart city. IoT Agenda, TechTarget [Internet]. 2017 Jul [cited 2026 Jul 1[3]]. Available from: https://internetofthingsagenda.techtarget.com/definition/smart-city
9. Wikipedia contributors. Smart city. Wikipedia, The Free Encyclopedia [Internet]. [cited 2026 Jul 1[3]]. Available from: https://en.wikipedia.org/wiki/Smart_city
10. Villanueva-Rosales N. Semantic-enhanced living labs for better interoperability of smart cities solutions. In: Proceedings of the IEEE International Smart Cities Conference; 2016 Sep.
11. Camero A, Alba E. Smart city and information technology: A review. Cities. 2019;93:84-94.
12. Umansky M. Autonomous agents in smart cities. SmythOS [Internet]. 2025 [cited 2026 Jul 1[3]]. Available from: https://smythos.com/managers/ops/autonomous-agents-in-smart-cities
13. Samih H. Smart cities and Internet of Things. J Inf Technol Case Appl Res. 2019;21(1):3-12.
14. Mohanty SP, Choppali U, Kougianos E. Everything you wanted to know about smart cities. IEEE Consum Electron Mag. 2016;5(3):60-70.
15. Sadiku MNO, Musa SM, Nelatury SR. Internet of Things: An introduction. Int J Eng Res Adv Technol. 2016;2(3):39-43.
16. Mohanty SP, Choppali U, Kougianos E. Everything you wanted to know about smart cities. IEEE Consum Electron Mag. 2016;5(3):60-70.
17. Sadiku MNO, Tembely M, Musa SM. Big data: An introduction for engineers. J Sci Eng Res. 2016;3(2):106-108.
18. Manus. Manus: Hands On AI [Internet]. 2026 [cited 2026 Jul 1[3]]. Available from: https://manus.im
19. StartUs Insights. Discover groundbreaking smart city technology in 2025 & beyond [Internet]. 2025 [cited 2026 Jul 1[3]]. Available from: https://www.startus-insights.com
20. Sanchez-Gallegos DD. Smart cities: A systematic review of emerging technologies.
21. Albino V, Berardi U, Dangelico RM. Smart cities: Definitions, dimensions, performance, and initiatives. J Urban Technol. 2015;22(1):3-21.
22. Sivaramakrishnan S. 3 reasons why Singapore is the smartest city in the world. World Economic Forum [Internet]. 2019 Nov 14 [cited 2026 Jul 1[3]]. Available from: https://www.weforum.org
23. Wilson P. State of smart cities in UK and beyond. IET Smart Cities. 2019 Apr.
24. Veselitskaya N, Karasev O, Beloshitskiy A. Drivers and barriers for smart cities development. Theor Empir Res Urban Manag. 2019;14(1):85-110.
25. Kresin F. Smart cities value their smart citizens. In: Mamadouh V, van Wageningen A, editors. Urban Europe. Amsterdam: Amsterdam University Press; 2016.
26. Lööf H, Nabavi P. Increasing returns to smart cities. Reg Sci Policy Pract. 2013;5(2):255-262.
27. DuPuis N, Rainwater B. Trends in Smart City Development. Washington (DC): National League of Cities, Center for City Solutions and Applied Research; 2017 Jan.
28. Brindley Technologies. Smart transportation [Internet]. [cited 2026 Jul 1[3]]. Available from: https://www.brindleytech.com/smart-transportation
29. Cata M. Smart university, a new concept in the Internet of Things. In: Proceedings of the 14th International Conference on Networking in Education and Research; 2015. p. 195-197.
30. Loffreda D. Tomorrow's cities: Evolving from "smart" to adaptive. Ciena Insights. 2019 Apr 16.
31. Batt M, *et al*. Smart cities of the future. Eur Phys J Spec Top. 2012;214:481-518.
32. Patrick G. Smart cities of the future: How technology is transforming urban life and infrastructure. 2026 Mar.
33. Forbes Technology Council Expert Panel. 19 smart city technologies and how they'll transform urban living.

Forbes. 2024 Jul 16.
34. Mulquin MJ. Roles of IEC in supporting effective smart city standards. IET Smart Cities. 2019 Apr.
35. Sadiku MNO, Olaleye OD, Musa SM. Green cities: A tutorial. Int J Trend Res Dev. 2019;6(3):77-79.
36. Yigitcanlar T. Smart cities: An effective urban development and management model? Aust Planner. 2015;52(1):27-34.
37. Kumar TMV, editor. E-Governance for Smart Cities. Singapore: Springer-Verlag; 2015.
38. Gassmann O, Böhm J, Palmié M. Smart Cities: Introducing Digital Innovation to Cities. Bingley (UK): Emerald Publishing; 2019.
39. Pelton JN, Singh IB. Smart Cities of Today and Tomorrow: Better Technology, Infrastructure and Security. Cham: Copernicus; 2018.
40. Barlow M, Levy-Bencheton C. Smart Cities, Smart Future: Showcasing Tomorrow. Hoboken (NJ): John Wiley & Sons; 2018.
41. Green B. The Smart Enough City: Putting Technology in Its Place to Reclaim Our Urban Future. Cambridge (MA): MIT Press; 2019.
42. Sun H, Wang C, Ahmad BI. From Internet of Things to Smart Cities: Enabling Technologies. Boca Raton (FL): CRC Press; 2017.
43. Song H, Srinivasan R, Sookoor T, Jeschke S, *et al*. Smart Cities: Foundations, Principles, and Applications. Hoboken (NJ): John Wiley & Sons; 2017.
44. Bell S, Paskins J, editors. Imagining the Future City. London: Ubiquity Press; 2013.
45. Sharma P, Rajput S, editors. Sustainable Smart Cities in India: Challenges and Future Perspectives. Berlin: Springer International Publishing; 2017.
46. Townsend AM. Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia. New York (NY): W.W. Norton & Company; 2013.

How to Cite This Article

Sadiku MNO, Padi D, Sadiku JO. Smart cities: Technologies and components. Int J Future Eng Innov. 2026;3(4):29-38. doi:10.54660/IJFEI.2026.3.4.29-38.

Creative Commons (CC) License