Global Models of Smart Cities and Potential IoT Applications: A Review

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Abstract: As the world becomes increasingly urbanized, the development of smart cities and the deployment of IoT applications will play an essential role in addressing urban challenges and shaping sustainable and resilient urban environments. However, there are also challenges to overcome, including privacy and security concerns, and interoperability issues. Addressing these challenges requires collaboration between governments, industry stakeholders, and citizens to ensure the responsible and equitable implementation of IoT technologies in smart cities. The IoT offers a vast array of possibilities for smart city applications, enabling the integration of various devices, sensors, and networks to collect and analyze data in real time. These applications span across different sectors, including transportation, energy management, waste management, public safety, healthcare, and more. By leveraging IoT technologies, cities can optimize their infrastructure, enhance resource allocation, and improve the quality of life for their citizens. In this paper, eight smart city global models have been proposed to guide the development and implementation of IoT applications in smart cities. These models provide frameworks and standards for city planners and stakeholders to design and deploy IoT solutions effectively. We provide a detailed evaluation of these models based on nine smart city evaluation metrics. The challenges to implement smart cities have been mentioned, and recommendations have been stated to overcome these challenges.

Keywords: smart cities; IoT; ICT; urbanization; sensors; development; LTE; 5G

1. Introduction

Emerging Internet of Things (IoT) applications and services, including smart health, smart grid, smart water, smart cities, and intelligent transportation systems (ITS), are set to transform and disrupt the way we live and work. IoT is currently enabling billions of smart devices and sensors which are communicated and remotely operated via the Internet. Currently, the number of IoT connected devices is greater than 15 billion devices. By 2030, it is expected that the IoT will incorporate more than 29 billion smart devices, which represents three times of that in 2020 [1]. According to the International Data Corporation (IDC), the IoT spending forecast will rapidly grow from $726 billion in 2019 to $1.1 trillion in 2023. According to IoT Analytics’ global IoT enterprise spending dashboard, the IoT enterprise market size is forecasted to grow at a compound annual growth rate (CAGR) of 19.4% to $483 billion from 2022 until 2027 [2].

The IoT is denoted as machine-to-machine (M2M) communication; therefore, a staggering number of “things” will require ubiquitous connectivity [3]. These connected devices can range from household appliances and smart home devices to industrial equipment, vehicles, and even entire cities [4]. IoT devices are typically equipped with sensors that can collect data on their environment, such as temperature, humidity, and motion detection, as well as data on their own operation, such as power usage and performance [5]. This data is then transmitted to other devices or systems over the Internet, where it can be analyzed and used to inform decisions and actions.
There is an emerging consensus that cellular-based legacy fourth generation (4G) long-term evolution (LTE) and emerging 5G are the key technology candidates that can provide the required global IoT connectivity to such a staggering number of “things”. The 5G cellular system will be distinct from previous generations. Basically, the fundamental merits will not be combinations of old and new radio access technologies (RAT); 5G will also enable new-use cases and mobile communication requirements beyond 4G cellular networks. It will be a combination of 4G cellular standards and technologies, as well as new disruptive technologies such as mmWave and spectrum sharing. 5G will be propelled by whole new services and demand [6]. By 2030, it is projected that there will be billions of interconnected things with data rates of several Gbps, allowing for a personalized user experience with minimal latency and great reliability [3]. Cellular-based machine-to-machine (M2M) communications are one of the key IoT enabling technologies with huge market potential for cellular service providers deploying LTE networks. Massive IoT (MIoT) refers to the tens of billions of M2M devices, objects, and machines that require ubiquitous connectivity [3]. According to the global standards body 3GPP, a massive scale means deploying at least 1 million devices per square kilometer [3]. IoT applications span a wide range of use cases ranging from mission-critical applications with strict latency and reliability requirements (e.g., driverless vehicles) to those that require support of massive number of connected M2M devices with relaxed latency and reliability requirements (e.g., smart meters) [3].

The prior cellular generations were essentially designed to meet the needs of human-type communications (HTC) (e.g., voice, video, and data). However, in order to accelerate industry digitalization, 5G networks are projected to enhance industrial communications, as well. As a result, new industry stakeholders will be able to use novel services and networking capabilities. 5G technology is projected to provide connection and communication needs in vertical industries (e.g., automotive, healthcare, manufacturing, entertainment, and so on) in a cost-effective manner [7].

According to the United Nations (UN) the world population has reached 8.0 billion in 2022, which is more than three times that in 1950. The world population is projected to reach 8.5 billion in 2030, and to further increase to 9.7 billion in 2050 and 10.7 billion in 2100 [8]. In 1950, approximately 70% of the world population were residing in rural areas. The turning point occurred in 2007; for the first time in history, the global urban population exceeded the global rural population. In 2018, 55% of world population (i.e., 4.2 billion) resided in urban areas. This percentage is expected to reach 60% in 2030. In 2050, more than two-thirds (68%) of global population are projected to reside in urban areas, which is the reverse of that in the mid-twentieth century [9].

Due to the projected increased demand for urbanization [9], it is expected that the demand for smart cities and their applications and services will increase accordingly. According to Allied Market Research, the global smart cities market size was valued at $648.4 B and is expected to reach $6.0 T in 2030, growing at a CAGR of 25.2% from 2021–2030 [10]. Consequently, the number of smart cities which contribute to enhancing the inhabitants’ quality of life (QoL) will increase. According to a study produced by the smart city observatory, part of the IMD world competitive center (WCC), the number of smart cities has increased from 118 cities in 2021 to 141 cities in 2023 [11].

Adoption of IoT communication technologies such as low-power wide-area networks (LPWAN), for instance, LTE for machines (LTE-M), narrow band IoT (NB-IoT), cellular networks such as 4G/LTE and 5G are required for the realization of smart city concepts [3]. According to Global Suppliers Mobile Association (GSA), around 70 countries had 5G networks as of June 2022. 5G is partially deployed in approximately 15 countries [12]. 6G, the next generation mobile network, promises exponentially faster data speeds and lower latency than 5G [13]. As a result, the deployment of these connectivity technologies is a critical factor in the maturation of smart city projects. Such technologies also pose the groundwork for the IoT, a vast network of smart devices that collaborate to collect and analyze data and perform actions, making smart cities a reality [14].
The selection criteria of the model cities in the paper are based on the preliminary revision of studies, reports, and electronic websites that display the smart cities around the world. The interdependence on authentic studies from official administrations to obtain the information related to the smart cities’ models were selected from Africa [15], Asia [16], and Europe [17], for instance, European Parliament studies, International Telecommunications Union (ITU) studies, and official websites which provide details of smart cities.

The selected smart cities must achieve the following standards:

- The recurrence of the city’s appearance in more than one comprehensive study to analyze smart city projects.
- The availability of an official website or a special report for the city containing smart projects that have been implemented or are being implemented in the city.
- The same project within the smart city must have more than one source in the absence of an official website or report for the city.
- Cities should be as representative as possible of most geographical areas and different cultural and economic characteristics.
- Considering that the experiments under study include models for both directions of smart cities, existing cities that have already been developed to transform into smart cities, and new cities that already exist from first, second and third generation cities.

2. Smart City

Smart cities are urban areas that leverage technology and data to improve the quality of life for their citizens, increase efficiency and sustainability, and enhance economic development. These cities use interconnected technologies to collect and analyze data in real time, allowing them to make informed decisions and optimize resource use. Smart cities rely on a variety of technologies, such as sensors, IoT devices, artificial intelligence (AI), and machine learning, to collect data and automate processes as depicted in Figure 1. This data can then be used to improve city services, such as transportation, energy, waste management, and public safety [18].

![Figure 1. Smart City Applications.](image-url)
1. Smart Transportation: utilize IoT sensors to collect data on traffic flow, parking, and public transportation, optimizing routes and reducing congestion. Ultimately, this data could also be used to improve safety by detecting and alerting drivers of potential accidents [19].

2. Smart Energy: deploy IoT sensors to monitor and optimize energy usage in buildings and public spaces, reducing waste and carbon emissions [20,21].

3. Smart Waste Management: utilize IoT sensors to monitor waste levels in trash cans and dumpsters, optimizing garbage collection routes and reducing costs [22]. Predictive analytics: use machine learning algorithms to predict the amount of waste generated in different areas and schedule waste collection accordingly [23]. Recycling robots: deploy robots to sort and separate recyclable materials from general waste [24]. Smart bins: install smart bins that use sensors to detect when they are full and send alerts to waste collection teams [25]. Waste-to-energy systems: convert waste into energy through incineration, gasification, or anaerobic digestion [25].

4. Public Safety: use IoT sensors to monitor crime and traffic violations, as well as detecting natural disasters and emergencies, enabling faster response times and better disaster management [26].

5. Smart Water Management: use IoT sensors to monitor and optimize water usage in buildings and public spaces, reducing waste and conserving resources [27]. Smart water systems can be used by water utilities, businesses, and homeowners to monitor and control water usage. Overall, smart water systems offer a number of benefits that can help to conserve water, save money, and improve water management.

6. Smart Health: use of connected devices and sensors to monitor and manage various aspects of health. These devices can collect and transmit data to healthcare providers, caregivers, or the individuals themselves, allowing for better tracking and management of health conditions and improving overall health outcomes [28].

7. Smart Government: use of technology and data to improve the efficiency, effectiveness, and quality of government services and operations. It involves the integration of information and communication technologies (ICT) into government processes and services, with the aim of enhancing transparency, citizen engagement, and overall governance [29,30].

8. Smart Buildings: use of advanced technologies and systems to enhance their functionality, efficiency, and sustainability. These buildings are equipped with a wide range of sensors, control systems, and other IoT devices that enable them to collect and analyze data about their environment and occupants in real time [31].

9. Smart Manufacturing: utilize advanced technologies such as the IoT, big data analytics, AI, robotics, and automation to optimize the manufacturing process. It aims to create a more efficient and flexible manufacturing system that can adapt to changing market demands, reduce costs, and improve product quality [32].

10. Unmanned Aerial Vehicles (UAV): a type of aircraft that is operated remotely without a human pilot on board. UAVs can be either controlled by a human operator on the ground or can be programmed to operate autonomously. They are commonly used for military, commercial, scientific, and recreational purposes and have become increasingly popular in recent years due to advances in technology and lower costs [33].

11. Robotics: robotics and the Internet of Things (IoT) play a crucial role in shaping smart city applications by integrating physical devices and intelligent systems with the city’s infrastructure [34]. These technologies enable the development of innovative solutions to improve efficiency, sustainability, and the overall quality of life for citizens. These are just a few examples of how robotics and IoT technologies are transforming urban environments into smarter, more sustainable, and efficient cities [34,35]. As technology continues to advance, we can expect even more innovative applications to emerge, improving the way we live and interact with our surroundings.

To implement smart cities, governments and businesses must work together to develop and deploy IoT technologies, as well as ensure the security, privacy, and interoperability of
the systems [36]. Smart cities require investment in infrastructure and innovation, and they can create significant benefits for citizens, businesses, and the environment. Overall, the goal of smart cities is to create more liveable, sustainable, and efficient urban environments for their citizens, while also reducing the environmental impact of cities and promoting economic growth [37].

2.1. Smart Transportation

As the number of vehicles increases, the transportation and logistics services represent a promising market for M2M communications. According to Statista, revenue in the passenger car market is expected to reach $1029B in 2023. The revenue in the passenger car market is expected to show an annual growth rate of +1.74%, resulting in a projected market volume of $2067 B in 2027 [38]. These emerging vehicles will be equipped with IoT sensors and actuators [3]. In addition, roads and transported goods are equipped with devices that enable the transportation and freight corporations to seamlessly track the vehicles and the goods by updating the status of delivery to the customers [39].

2.1.1. Logistic Services

The supply chain can work efficiently by enabling M2M sensors to track goods and vehicles in real time. M2M logistic services enable total surveillance on the status of raw materials, products, storage, transportation, and after-sell services by monitoring temperature, humidity, and light. If the status has a problem (i.e., an emergency event), the M2M sensor will transmit an alerting message to the M2M server to take the proper decision via the core network [40]. In addition, the M2M logistic services can also track the inventory in the warehouses by enabling the stakeholders to monitor the market dynamics and take the appropriate decision regarding either to launch sale or to refill. The aforementioned policies will help to reduce the occupied spaces in the warehouses, reducing the waiting times for the customers and consequently gaining the customers’ satisfaction [41]. These services can help companies improve efficiency, reduce costs, and increase safety by providing real-time visibility and data-driven insights. The logistic transportation IoT services include:

1. **Asset Tracking**
   Deploy IoT sensors to track the location and condition of cargo, containers, and other assets in real time. This can help companies optimize logistics and reduce the risk of theft or loss [42].

2. **Condition Monitoring**
   Utilize sensors to monitor the condition of goods during transportation, including temperature, humidity, and other environmental factors. This can help companies ensure the quality and safety of their products [43].

3. **Predictive Maintenance**
   IoT sensors can be used to monitor the condition of vehicles and equipment in real time and predict when maintenance is needed. This can help companies reduce downtime and extend the life of their assets [44,45]. Overall, logistic transportation IoT services can provide companies with a range of benefits, including improved efficiency, reduced costs, increased safety, and enhanced customer satisfaction.

2.1.2. Electric Vehicles

The intelligent transportation systems (ITS) depend on the M2M communications accompanied by the roads, which are equipped with IoT sensors and actuators which contribute to regulating the traffic flow, vehicle navigation and/or safety [46]. If the vehicle operator is sleeping, the sensors will alert the operator to avoid accidents. In addition, the M2M sensors equipped in the roads will guide the operators to the closest charging station, as it has all information of the vehicle including the battery charging level [47].
IoT sensors installed in the road and high definition (HD) cameras [14] equipped in the traffic lights are integrated together to regulate and control the vehicles’ traffic flow in the street [48]. Furthermore, in case of an accident, the M2M sensors installed in the roads and vehicles will detect the location of the accident which enables the governmental agencies to act immediately. Electric vehicles (EVs) are a rapidly growing industry that is helping to reduce carbon emissions and improve air quality [49]. With the rise of the IoT, there are numerous IoT applications that can be used to enhance the capabilities of electric vehicles as illustrated in Figure 2.

![Figure 2. Electric Vehicle M2M Applications.](image)

1. Remote monitoring:
   Monitor the health and status of electric vehicle components, such as batteries, motors, and charging systems using IoT sensors. This information can be transmitted to a central server for analysis, allowing vehicle owners to receive alerts if there are any issues with their vehicle [50].

2. Smart charging:
   Optimize the charging of electric vehicles, ensuring that they are charged at the most efficient times and using the most cost-effective energy sources. This can help to reduce the strain on the power grid and reduce the cost of charging for vehicle owners [51,52].

3. Vehicle-to-Grid (V2G) communication:
   Enable V2G communication, allowing electric vehicles to communicate with the power grid and provide energy back to the grid when it is needed. This can help to balance the load on the grid and reduce the need for additional power generation [53,54].

4. Predictive maintenance:
   Analyze data from electric vehicles to predict when maintenance is needed, allowing vehicle owners to schedule maintenance before issues arise. This can help to reduce downtime and extend the life of vehicle components [55].

5. Driver behavior monitoring:
   Deploy IoT sensors to monitor driver behavior, including acceleration, braking, and speed. This can help promote safer driving practices and optimize energy consumption. Ul-
ultimately, IoT applications can greatly enhance the capabilities of electric vehicles, improving their efficiency, reliability, and cost-effectiveness [56].

2.1.3. Smart Parking

Smart parking is the use of technology to improve the efficiency of parking management. This can include various tools and services, such as sensors, mobile apps, and real-time data analysis, to help drivers find parking spaces quickly and easily. Some of the benefits of smart parking services include reduced congestion, increased revenue for parking operators, and improved customer experience for drivers. For example, smart parking services are the use of sensors that detect whether a parking spot is occupied or not. This information can then be transmitted to a central database, which can be accessed by drivers through a mobile app. This allows drivers to find available parking spots in real time, reducing the amount of time spent searching for a spot and ultimately reducing congestion on the roads. These days, driving and parking a car in urban cities is challenging. For instance, the number of vehicles entering Manhattan (only the business district) in 2017 exceed 700 k per day [57,58]. Finding parking for these cars is becoming more difficult if the number of parking spots across New York City (NYC) is only between 3.4 M to 4.4 M. To overcome this problem, M2M sensors placed on roads will promptly guide the vehicle operators to the unoccupied spots on the street. This service will save energy (fuel) and money and will enable the government to monitor the occupancy level of available parking spots [59].

1. Smart vehicle counting

Within 2010 to 2050, the population of the urban cities will increase from 3.6 billion to 6.3 billion inhabitants with 80% increasing rate [60]. By 2035, the population of the US will exceed 370M [61], and the world population will approximately 8.8B inhabitants. On average, the number of vehicles running on the roads will reach 2B by 2035 [39,62]. According to a report by Allied Market Research, the global smart vehicle market is expected to reach $2.2 trillion by 2030, growing at a compound annual growth rate (CAGR) of 40.1% from 2021 to 2030 [63]. This absolutely will pose a serious challenge to manage the traffic control, intelligent transportation, and city management. In order to tackle this problem, employing the M2M sensors to collect data which provide accurate vehicle detection and measuring and controlling the traffic flow [64].

2. Passenger services

One of the utmost passenger services is the e-ticketing system [65]. Ticketing systems of traditional transportation systems are manual, and some of them may be semi-automatic and/or automatic systems used to collect fares. The near field communication (NFC)-based ticketing system will be utilized as the M2M node at the gates or exits in the airport terminals, or train stations scan the passenger identity using NFC-enabled user equipment (UE) [66]. The NFC-enabled UE is scanned at the M2M node; the M2M will send its code to the M2M server through the core network. Based on the tariff table, the traveled distance, and the class of the ticket (e.g., economy, business, and first class) the fare will be withdrawn from the passenger’s bank account or credit card. Mobile ticketing raises customer satisfaction along with the ticketing system’s effectiveness.

3. Fleet management

Nowadays, numerous cargo ships are voyaging through the open oceans. These containers’ delivery services may be affected for many reasons, including piracy, physical damage, and delivery delay. To address this problem, M2M communications can be used in fleet management by developing a superior management system to deliver freight promptly between different regions [67]. Tracking of vehicles and cargos is enabled by installing M2M sensors that collect locations, delivery status, and climate data, which are used to reduce accidents and improve the fuel consumption efficiency, hence increasing the fleet management effectiveness [68].
2.2. Smart Energy

IoT services are a suite of technology-based solutions designed to optimize the production, distribution, and consumption of energy [21,69]. These services use sensors, data analytics, and machine learning to collect and analyze data on energy usage patterns and enable the automation and control of energy systems.

2.2.1. Smart Grid

A modern electricity grid that leverages IoT technologies to optimize energy distribution, consumption, and management. Smart grid solutions can help reduce energy consumption, increase efficiency, and minimize environmental impact [69,70].

2.2.2. Demand Response

Demand response is a change in the power consumption of an electric utility customer to better match the demand for power with the supply [71]. Demand response can be used to reduce peak demand, which can help to avoid blackouts and brownouts. IoT sensors can be deployed to manage energy demand by adjusting energy usage during peak demand times. This can help reduce the need for costly power generation and distribution infrastructure [3,69].

2.2.3. Distributed Energy Resources (DERs)

Managed distributed energy resources (DERs), such as solar panels and wind turbines, enabled energy providers to optimize energy distribution utilizing IoT sensors. DERs are becoming increasingly important as the electricity grid becomes more decentralized. As more and more people generate their own electricity, DERs will play a key role in ensuring the reliability and resilience of the grid [71].

2.2.4. Grid Monitoring

IoT sensors can be deployed to simultaneous monitor grid performance, enabling utilities to respond quickly to any problems or outages. This can help reduce downtime and improve reliability [69,72].

2.2.5. Power Quality Monitoring

The quality of electricity being distributed can be monitored, enabling utilities to identify and resolve any issues that may affect power quality using IoT sensors [72]. A combination of IoT devices, data analytics, and communication technologies are required to implement smart energy solutions. However, the potential benefits include reduced energy consumption, which improves efficiency, and environmental impact, which has a significant impact on both individuals and communities [3,69].

2.2.6. Smart Lighting

Smart lighting employs IoT sensors to adjust lighting levels based on occupancy and daylight levels. This can help reduce energy consumption and save costs while still providing adequate lighting. Another M2M application was implemented in smart homes, smart offices, smart cities, and streets [4,14]. Smart lighting systems impact energy savings in the cities around the world. Currently, 55% of the world population is residing in urban cities. As the growth accelerates rapidly, 68% of the population are predicted to live in urban cities by 2050 globally. By 2030, there are 43 megacities with more than 10 million residents predicted [73]. These statistics pose challenges to city management and smart buildings in terms of energy utilization efficiency. As smart cities tend to be green, the sources of greenhouse gas (GHG) emissions must be reduced [14]. Electricity is one of GHG emission sources which represents 27% of the total US GHG emission in 2018 [74]. The dominant electricity source of GHG emissions is the residential and commercial section, which represents 32% [74]. Reducing GHG emissions can be accomplished by reducing electricity usage and peak demand by increasing the utilization efficiency in residential and
commercial buildings. Based on the report published by the World Council on City Data (WCCD) in 2017, GHG emissions were reduced by 63% in the city of Los Angeles due to switching to light emitting diode (LED) lighting [14]. By 2025, the global call of switching lighting systems to 100% smart LED lighting will contribute to the reduction of the lighting share of the global energy consumption from 15% to 8% [75,76].

2.2.7. Energy Storage

The use of energy storage solutions such as batteries and capacitors can be optimized [69]. This can help reduce energy waste and provide a more reliable source of energy in areas with unreliable energy supply. Implementing smart energy solutions requires a combination of IoT devices, data analytics, and communication technologies [3]. However, the potential benefits of smart energy, including reduced energy consumption, increased efficiency, and minimized environmental impact, can have a significant impact on both individuals and communities [77].

2.3. Smart Waste Management

IoT applications leverage the power of the Internet of Things (IoT) to enhance waste management systems, making them more efficient, cost-effective, and environmentally friendly [78]. These applications utilize various IoT technologies to monitor, collect, analyze, and manage waste in real time [79]. Overall, smart waste management IoT applications offer a holistic approach to handling waste, promoting sustainability, reducing operational costs, and contributing to a cleaner environment. As IoT technology continues to evolve, these applications are likely to become even more advanced and widespread.

2.3.1. Smart Waste Bins

IoT-enabled waste bins are equipped with sensors that can detect the fill level of the bin. These sensors can use ultrasonic, infrared, or weight-based technologies to measure the waste level. When the bin reaches a certain threshold, it sends an alert to waste collection teams, optimizing the collection process by reducing unnecessary trips and preventing overflow [80].

2.3.2. Route Optimization

IoT devices on waste collection vehicles enable real-time tracking of their location and status. These devices can use GPS technology to find the most efficient routes for waste collection, considering factors such as real-time traffic conditions and the fill levels of individual waste bins. Optimized routes reduce fuel consumption, emissions, and operational costs [81].

2.3.3. Environmental Monitoring

IoT sensors can be deployed in landfills to monitor environmental conditions such as methane emissions, temperature, and air quality. Real-time monitoring helps in early detection of potential issues and allows for timely mitigation actions, ensuring compliance with environmental regulations [82].

2.3.4. Recycling Management

IoT applications can facilitate the separation and sorting of recyclable materials. Smart recycling bins equipped with sensors can help users identify the correct recycling category for their waste items, promoting proper recycling practices [83].

2.3.5. Public Awareness and Education

Smart waste management IoT applications can also be used to raise public awareness about waste management and encourage responsible waste disposal behaviors. Interactive displays on waste bins or smartphone apps can provide information about recycling
guidelines, waste reduction tips, and the environmental impact of different waste disposal methods [84].

2.3.6. Data Analytics

IoT-generated data from waste bins, collection vehicles, and landfill sensors can be analyzed to identify patterns and trends in waste generation, collection efficiency, and recycling rates. This data-driven approach allows municipalities and waste management companies to optimize their operations further and make informed decisions [85].

2.3.7. Remote Monitoring and Maintenance

IoT devices enable remote monitoring of waste management infrastructure, such as waste compactors and incinerators. This allows for proactive maintenance and reduces downtime, ensuring that waste management systems operate efficiently [86].

2.4. Public Safety

The goal of public safety is to create a safe and secure environment for all. This includes protecting people from crime, fire, and other hazards. Public safety also includes ensuring that people have access to emergency services when they need them. There are many different organizations that play a role in public safety. These include law enforcement agencies, fire departments, emergency medical services (EMS), and disaster response agencies [87]. These organizations work together to prevent crime, respond to emergencies, and protect the public from harm. Public safety IoT applications use connected devices and sensors to enhance public safety and security [88]. Some public safety IoT applications follow.

2.4.1. Traffic Management

Monitoring traffic conditions, detecting accidents or incidents, and optimizing traffic flow can improve response times for emergency services [88]. Traffic management applications are essential tools used to ensure the safety of road users and pedestrians, as well as to improve the efficiency of traffic flow. Here are some examples of traffic management and public safety applications:

1. Intelligent Traffic Systems (ITS)

ITS are systems that use advanced technologies such as sensors, cameras, and communication networks to monitor and manage traffic on roads [89]. These systems provide real-time information to drivers about traffic conditions, road closures, accidents, and other incidents, enabling them to make informed decisions about their routes and travel times.

2. Automated Traffic Enforcement (ATE)

Systems use cameras and sensors to automatically detect and enforce traffic violations such as speeding, red-light running, and illegal parking [90]. These systems are often used to improve public safety by reducing the number of accidents caused by irresponsible driving.

3. Emergency Vehicle Prevention (EVP)

EVP systems are used to provide emergency vehicles, such as ambulances and fire trucks, with high priority access to intersections. These systems use transmitters on emergency vehicles to communicate with traffic signals [76], allowing them to change to green lights and clear the way for the emergency vehicle.

4. Pedestrian Detection Systems (PDS)

PDS systems use sensors and cameras to detect pedestrians in crosswalks and alert drivers to their presence [91]. These systems are especially useful in areas with high pedestrian traffic, such as urban centers and school zones.

5. Variable Message Signs (VMS)
VMS are electronic signs that display real-time information about traffic conditions, road closures, and other relevant information to drivers. These signs are used to provide drivers with up-to-date information that can help them make immediate decisions about their routes and travel times [92]. In general, these traffic management and public safety applications are essential tools for ensuring the safety of road users and improving the efficiency of traffic flow.

2.4.2. Emergency Response

Emergency response applications automatically detect emergencies such as fires, gas leaks, or natural disasters and send alerts to emergency responders or the public. They are software tools designed to help emergency responders quickly and efficiently respond to emergencies, manage incidents, and communicate with each other during a crisis [93]. These applications can help emergency responders coordinate resources, share information, and make better decisions in real time. The emergency response public safety applications comprising:

1. Dispatch Systems

These systems allow dispatchers to receive emergency calls, quickly identify the location and nature of the emergency, and dispatch the appropriate resources to the scene [94]. These systems also provide real-time communication tools that enable responders to communicate with each other and share critical information.

2. Incident Management Systems

These systems help emergency responders manage incidents by providing a centralized platform for sharing information, tracking resources, and coordinating response efforts [95]. They can also provide in situ awareness tools that allow responders to monitor the status of the incident in real time.

3. Mapping and GIS Applications

These applications use geographic information system (GIS) technology to provide responders with detailed maps and location data that can help them navigate to the scene of an emergency, identify hazards and resources, and plan response strategies [96].

4. Emergency Mobile Apps

These apps provide emergency responders with onsite access to critical information and communication tools [97]. They can also provide real-time updates on incident status, resource availability, and other important information.

5. Social Media Monitoring Tools

These tools enable emergency responders to monitor social media platforms for information about emergencies, identify trends and patterns in user-generated content, and quickly respond to emerging threats or issues [98]. Eventually, emergency response public safety applications will help emergency responders work more efficiently and effectively, which can ultimately save lives and reduce the impact of disasters and emergencies.

2.4.3. Public Health Monitoring

Public health monitoring devices monitor air quality, detect pathogens, and track the spread of diseases, which can help prevent outbreaks and protect public health. These devices are essentially used to protect and improve the health and safety of individuals and communities [99]. The public health monitoring applications involve:

1. Disease Surveillance

Public health officials use disease surveillance systems to monitor the incidence and prevalence of infectious diseases, such as COVID-19, influenza, and tuberculosis [100]. These systems allow health officials to detect outbreaks early, track disease spread, and develop targeted interventions to prevent the further spread of disease.
2. Emergency Management

Emergency management systems are used to coordinate responses to natural disasters, terrorist attacks, and other emergencies [101]. These systems provide real-time information about the location and severity of incidents, as well as resources available to respond to them.

3. Environmental Monitoring

Environmental monitoring systems are employed to detect and respond to environmental hazards, such as air pollution, water contamination, and hazardous waste [102]. These systems allow officials to identify potential health risks and take measures to protect the public from harm.

4. Food Safety

Food safety systems are deployed to monitor food production, processing, and distribution to prevent foodborne illnesses. These systems track outbreaks of foodborne illness and identify the sources of contamination, allowing officials to take action to prevent future outbreaks [103].

5. Public Health Communication

Public health officials use communication systems to disseminate information about health risks, promote healthy behaviors, and encourage the public to take action to protect their health [104]. These systems use various channels, such as social media, traditional media, and public service announcements, to reach a broad audience and provide information that is timely and relevant. Ultimately, public health monitoring and public safety applications are essential tools that help protect and improve the health and safety of individuals and communities.

2.4.4. Infrastructure Monitoring

Infrastructure monitoring is an important aspect to ensure public safety. By monitoring infrastructure, such as bridges, roads, buildings, tunnels, pipelines, and other critical facilities, potential safety hazards can be detected early, and appropriate action can be taken to prevent accidents and minimize damage [105]. Every government must monitor and maintain a broad range of infrastructure, including bridges, tunnels, dams, parks, roads, cables, and pipes. IoT devices are utilized to efficiently monitor the public infrastructure equipped with sensors and RFID tags [106]; this contributes to a reduction of diurnal maintenance and inspection costs by utilizing the transportation traffic-rerouting strategies, for instance, management of parking facilities.

1. Bridge safety monitoring

Infrastructure monitoring systems can monitor bridges for structural damage, wear and tear, and other factors that can affect their safety [107]. This can help prevent accidents and ensure that bridges are safe for public use.

2. Building safety monitoring

Infrastructure monitoring systems can also be used to monitor buildings for safety hazards such as gas leaks, fires, or structural damage [108]. This can help prevent accidents and ensure that buildings are safe for occupancy.

3. Road safety monitoring

Infrastructure monitoring systems can monitor roads for potential hazards such as potholes, cracks, and other damage that can cause accidents. By detecting these hazards early, appropriate action can be taken to prevent accidents and ensure that roads are safe for public use [109].

4. Natural disaster monitoring
Infrastructure monitoring systems can also be used to monitor natural disasters such as earthquakes, hurricanes, and floods. By detecting these events early, appropriate action can be taken to minimize damage and ensure public safety. In general, infrastructure monitoring plays an important role in ensuring public safety [110]. By detecting potential safety hazards early and taking appropriate action, infrastructure monitoring systems can help prevent accidents, minimize damage, and ensure that critical infrastructure is safe for public use.

5. Asset tracking

Deploying IoT devices to track high-value assets such as vehicles, equipment, and cargo can help prevent theft and improve supply chain management [111]. Asset tracking has numerous public safety applications, comprising the following applications:

2.4.5. Tracking Emergency Response Vehicles

Asset tracking can be used to monitor the location of emergency response vehicles such as ambulances, police cars, and fire trucks [112]. This can help dispatchers to send the nearest available vehicle to an emergency situation and enhance response times.

1. Tracking Valuable Equipment

Monitoring valuable equipment, such as firearms, radios, and body cameras [113], can help ensure that these items are always accounted for and not lost or stolen. The best way to track valuable equipment will depend on the specific needs of the organization. If accuracy is critical, then GPS tracking is the best option. If affordability is important, then RFID tracking or barcode scanning may be better options.

2. Tracking Prisoners

Monitoring the location of prisoners who are on parole or probation can help ensure that they are complying with the terms of their release and not engaging in any criminal activity [114].

3. Tracking Stolen Vehicles

Monitoring the location of stolen vehicles can help law enforcement to quickly recover the stolen vehicle and apprehend the thief [115]. The best way to track a stolen vehicle will depend on the specific circumstances of the theft. If a vehicle has a built-in GPS tracker, it will be utilized to track the vehicle’s location. If the vehicle does not have a built-in GPS tracker, a GPS tracker can be purchased and installed in the vehicle.

4. Tracking Evidence

Asset tracking can be used to monitor the location of evidence in criminal investigations. This can help ensure that the evidence is properly secured and not tampered with [116]. Ultimately, asset tracking can help public safety officials to better monitor and manage their resources, leading to improved response times, reduced losses, and better outcomes for the communities they serve. Ultimately, public safety IoT applications can help reduce crime, improve emergency response times, and enhance public safety and security.

2.5. Smart Water Management

Nowadays, the demand for water continues rapidly as the population grows significantly. Since the last century, global water consumption is more than twice the rate of world population increase. The water usage is predicted to escalate 50% from 2007 to 2025 in the emerging countries and 18% in the developed countries [117]. By 2025, two-thirds of the world’s population may face water shortages. A variety of enterprises depend on water for manufacturing and management. Absolutely, a large percentage of the wasted water due to the aging and leakage of the pipelines, for instance, according to the world bank, the annual global value of water produced and lost by utilities is close to $14 billion [118]. To overcome this problem, smart cities must be capable of monitoring the water supply to ensure the delivery of adequate water supply to the residential and commercial buildings.
(i.e., water saving systems). The smart cities are equipped-M2M sensors which could be used to remotely control and report any leakage in the pipelines. M2M sensors measure the flow of the water inside the pipes regularly, if an emergency triggered, the sensor transmits an alarming message to the M2M server to take the proper decision if the water leakage is beyond a normal range.

2.6. Smart Health

Deploying technology, data analytics, and other advanced techniques to improve healthcare outcomes and make healthcare delivery more efficient, effective, and accessible. Smart health applications include wearable devices, remote monitoring tools, telemedicine platforms, electronic health records (EHRs), and artificial intelligence (AI) algorithms. Remote Patient Monitoring, Telemedicine, Medication Management, Remote Surgery [119], and Asset Tracking [120]. The smart health care applications may be categorized into four major types:

2.6.1. Tracking and Monitoring

Tracking is the function used to identify the moving patient (i.e., knowing the current position of the tracked person) [121]. For example, the tracking of the patients diagnosed with The Novel Corona Virus (COVID 19) pandemic and consequently those patients are subject to self-isolation [122]. For the government authorities to ensure that those patients are in self-isolating orders, they must be tracked using IoT sensors. In addition, to track the number of people interacting with the patient to contain the virus spreading. Regarding the monitoring, IoT smart health application allows the remote monitoring of the high-risk patients by attaching sensors [122]. These sensors send an alarm to the control center if the high-risk patient (who is vulnerable to fatal consequences due to critical conditions) has dangerous circumstances [123]. For example, if an elderly person falls or a diabetic person has hyperglycemia or hypoglycemia.

2.6.2. Authentication and Identification

Authentication and identification in smart health are needed in multiple forms. Accurate patient identification is crucial and critical to avoid the assignment of wrong medication in terms of (dosage, time, frequency, route, and procedure). Authentication is an important security issue, especially with devices attached to the human body, for instance, the pacemaker, which is a small device placed underneath the skin in the chest to regulate the heartbeats [124]. If a hacker has the ability to intervene in the operation of the pacemaker by increasing or decreasing the heart rate, it will result in a life-threatening issue. In addition, the real-time medical data record, privacy, and maintenance must be authenticated to avoid the leakage of the patient data and to ensure the patient’s privacy protection [125].

2.6.3. Data Collection

Automatic data collection is required to reduce the processing and treatment time required to implement a medical treatment plan. If a medical device is attached to human body to measure the blood glucose for a diabetic patient, if the blood glucose in high, so sensor has to send the data automatically to the patient’s physician (in the control center) to order the medication promptly. After that, physician sends the order back to the attached device to inject the enough insulin to consume the excessive glucose in the blood stream [126]. The previous situation is vital and represents instantaneous data collection and decision making. The energy consumption may be reported once at a time. The M2M applications may be delivered or reported in many ways:

1. Periodic reporting
2. On demand reporting
3. Scheduled reporting
4. Event-driven reporting
2.7. Smart Government

Smart government utilizes technology and data to enhance the efficiency and effectiveness of government services, improve citizen engagement, and promote transparency and accountability. This approach involves the integration of various technologies, such as big data, artificial intelligence, the IoT, and blockchain, to create a more responsive and proactive government that delivers better outcomes for citizens. Smart government initiatives can encompass a range of areas, including public safety, transportation, healthcare, education, and environmental sustainability [78]. For instance, governments can use big data and AI to analyze crime patterns and predict criminal activity, improve traffic flow and reduce congestion through the use of smart transportation systems, or use IoT sensors to monitor air and water quality in real time. Smart government can also promote citizen engagement and participation through the use of digital platforms and tools that enable citizens to access government services and information, provide feedback, and participate in decision-making processes. This can lead to a more transparent and accountable government that is more responsive to the needs of its citizens. Overall, smart government initiatives have the potential to improve the efficiency and effectiveness of government services, enhance citizen engagement and participation, and promote transparency and accountability in government [127].

2.8. Smart Building

We are living in an environment surrounded by many electric and electronic appliances, for instance, television sets, microwaves, refrigerators, dishwashing machines, air conditioners, etc. To remotely control and monitor these devices, IoT sensors and actuators will be installed to efficiently utilize the energy consumed by these appliances. Heating and cooling might be adjusted using the IoT sensor depending on the current meteorological conditions to sustain the desired temperature [128]. The lighting may be adjusted based on the number of people occupying the room utilizing the motion sensor. The street lighting may be adjusted by utilizing the light sensors to save energy consumption. The motion outside the property will be detected using motion sensors which can be utilized to detect any burglary activity [128]. The electric appliances could be automatically switched off in case of inactivity mode (i.e., idle mode) to reduce energy consumption especially in the prime time. At the prime time, IoT sensors will contribute to the money saving due to the high price of the electricity during this time. On the other hand, the price at other times will be much cheaper than the price the prime time [129]. On the consumer side, the customers may sell the electricity during the rush hour and buy it or consume it during the non-rush hour time.

2.9. Smart Manufacturing

Smart manufacturing is the integration of advanced technologies, such as the IoT, AI, machine learning, robotics, and big data, into industrial processes to optimize efficiency, productivity, and flexibility [130]. The main goal of smart industry is to create a fully connected and automated production system that is more efficient, flexible, and customizable than traditional manufacturing processes [131]. By using real-time data analytics and advanced automation technologies, smart industry enables businesses to optimize their operations, reduce costs, and enhance product quality [132].

2.9.1. Predictive Maintenance

Predictive maintenance (PdM) is a maintenance strategy that uses data analysis to predict when equipment is likely to fail. This allows maintenance to be scheduled proactively before a failure occurs. PdM can be a valuable tool for smart manufacturing, as it can help to improve uptime, reduce costs, and increase reliability. Employing sensors and AI are used to predict when equipment will fail and contribute to preventing costly downtime [133].
2.8.2. Digital Twins

Creating virtual models of physical assets helps optimize performance and reduce maintenance costs [134]. Overall, smart industry represents a major shift in the way businesses approach industrial production and has the potential to transform entire industries.

2.8.3. Industrial Internet of Things (IIoT)

Connecting machines, sensors, and devices throughout the manufacturing process to collect and share data in real time enables better monitoring, predictive maintenance, and process optimization [135].

2.8.4. Big Data Analytics

Big data analytics is a powerful tool that can be used to improve a variety of processes in smart manufacturing. It is still important to have a good understanding of the manufacturing process and to use big data analytics in conjunction with other tools and techniques. Utilizing large volumes of data collected from various manufacturing processes helps gain insights, identify patterns, and make data-driven decisions [136].

2.9. Unmanned Aerial Vehicle (UAV)

UAV is a type of aircraft that is operated remotely without a human pilot on board. UAVs can be either controlled by a human operator on the ground or can be programmed to operate autonomously. They are commonly used for military, commercial, scientific, and recreational purposes and have become increasingly popular in recent years due to advances in technology and lower costs. UAVs equipped with IoT sensors can collect and transmit data in real time, enabling a variety of use cases across multiple industries [137].

2.9.1. Agriculture

UAVs equipped with sensors can be used to monitor crop health, collect data on soil moisture and nutrient levels, and identify areas in need of irrigation or fertilizer [138]. This can help farmers optimize their crop harvest, reduce costs, and minimize environmental impact. Eventually, UAVs can provide farmers with valuable data that can help them make more informed decisions about crop management, leading to higher yields, and increased sustainability. UAVs have a wide range of agricultural services including:

1. Crop Monitoring:

UAVs can be used to monitor crops for pests, diseases, and nutrient deficiencies. They can capture high-resolution images of the crops, which can be used to detect early signs of stress and other diseases based on AI algorithms [138]. In addition, these images may be utilized to identify the ideal time to harvest different crops.

2. Precision Agriculture:

UAVs equipped with specialized sensors can provide farmers with data on soil moisture, temperature, and other environmental factors. This data can be used to make more informed decisions about crop management, including planting and irrigation [139].

3. Crop Spraying:

UAVs can be used to spray crops with pesticides or fertilizers, which can reduce the need for manual spraying and minimize the risk of exposure to harmful chemicals [140]. Eventually, UAV-based crop spraying offers a number of potential benefits [141]. However, there are also some challenges that need to be addressed before they can become widely adopted [142].

4. Mapping:

UAVs can be used to create high-resolution maps of farms, including the layout of fields and buildings. This data can be used to plan future planting and construction projects [143]. They offer a number of advantages over traditional methods, such as ground-based surveying, and include accuracy, efficiency, and safety.
5. Irrigation Management:

UAVs can be used to monitor the effectiveness of irrigation systems. They can capture images of fields before and after irrigation, which can be used to determine the optimal amount of water to apply [144]. By using these systems, it will help to conserve water resources, which can be used in parallel with the smart water systems. Using such systems will contribute to high-quality crops.

2.9.2. Disaster Response

UAVs equipped with sensors can be used to assess damage and locate survivors in disaster zones, providing valuable information to first responders and enabling them to respond more effectively [145]. UAVs have become a valuable tool for disaster response and management due to their ability to quickly gather data, assess damage, deliver supplies to hard-to-reach areas, and deliver aid to those in need.

1. Search and Rescue:

UAVs equipped with thermal imaging cameras and other sensors can help search and rescue teams locate survivors in disaster zones, even in low-light or low-visibility conditions such as after a hurricane [146]. By determining the survivors’ locations, it will give the exact information to the first responder teams who provide nutrition and medication resources.

2. Disaster Mapping and Assessment:

UAVs equipped with high-resolution cameras and LiDAR sensors can quickly and accurately map disaster areas, helping authorities assess the extent of damage and plan response efforts [147]. Additionally, UAVs can be used to create detailed maps of disaster zones, including infrastructure damage, flood levels, and road conditions. These maps can help authorities prioritize response efforts and allocate resources more efficiently [148].

3. Delivery of Aid and Supplies:

UAVs could be utilized to deliver emergency supplies to inaccessible areas, such as medical supplies, food, and water [148,149]. UAVs are used to deliver aid to people in need. They offer a number of advantages over traditional methods, such as land vehicles and helicopters.

4. Communication Support:

UAVs can be equipped with cellular repeaters and other communication devices to provide temporary connectivity in disaster zones where communication infrastructure has been damaged or destroyed [150].

2.9.3. Infrastructure Inspection

UAVs equipped with sensors can be used to inspect infrastructure such as bridges, roads, and power lines, identifying potential problems and enabling maintenance teams to respond quickly [151]. UAVs have a wide range of applications in infrastructure inspection [152] due to their ability to provide high-resolution imagery and data and ability to access hard-to-reach areas safely and efficiently [151]. Eventually, the use of UAVs in infrastructure inspection will allow for more effective and accurate maintenance and repair decisions.

1. Bridge inspections:

UAVs can fly underneath and alongside bridges to capture high-resolution images and video of their structural components, such as joints, beams, and cables. This helps identify any damage or wear and tear and helps prioritize repairs at certain and specific points of damage at bridges [153,154].

2. Power line inspections:
UAVs can fly along power lines to inspect them for damage or vegetation growth that could cause power outages. The UAVs can capture high-resolution images and video of the power lines and also use thermal imaging to detect hotspots and potential faults [155]. However, there are also some challenges associated with using UAVs to inspect power lines: government regulations, technology, reliability, and cost.

3. Wind turbine inspections:

UAVs can fly close to wind turbines to inspect their blades and towers for damage. This helps identify any wear and tear, erosion, or cracks, which could cause potential malfunctions, resulting in multiple problems in the distribution networks [156].

4. Roof inspections:

UAVs can inspect roofs for damage, such as missing shingles, cracks, or leaks. They can also capture images of the roof’s overall condition and identify potential areas of weakness [157]. The problems resulting from roof damage are time-sensitive and require quick decision making. For an effective decision, a big data-based AI algorithm may be utilized to provide these decisions.

2.9.4. Delivery Services

UAVs equipped with sensors can be used to deliver packages and goods in remote or hard-to-reach areas. This can provide faster and more efficient delivery services, especially in areas with limited transportation infrastructure [158]. Delivery services are increasingly turning to UAVs as methods of delivering goods quickly and efficiently. Overall, UAVs have the potential to revolutionize the delivery industry by providing a faster, more efficient, and cost-effective means of delivering goods. However, the technology is still relatively new and there are many regulatory and technical challenges that need to be addressed before UAVs can be widely used for delivery services [159]. Implementing UAV IoT applications requires a combination of technologies, such as sensors, communication systems, and data analytics. However, the potential benefits of UAV IoT applications, including improved efficiency, reduced costs, and increased safety, can have a significant impact on multiple industries.

1. Last-mile delivery:

UAVs can be used to deliver packages to customers’ doorsteps [160] or other inaccessible locations in the last mile of the delivery process, reducing the time and cost of delivery [161]. UAVs offer a number of advantages over traditional methods, such as ground-based delivery and car-based delivery, including speed, accuracy, and efficiency.

2. Medical supply delivery:

UAVs can be used to transport medical supplies such as drugs, blood, and vaccines to hospitals or other medical facilities in emergency situations or in hard-to-reach areas [160,162]. The benefits of using UAVs to deliver medical supplies include saving lives, reducing costs, and increasing efficiency.

3. Retail delivery:

UAVs can be used to transport products from warehouses or distribution centers to retail stores, improving the efficiency of the supply chain [163]. The benefits of using UAVs for retail delivery may include increased customer satisfaction by delivering products faster, reducing delivery cost, and improving environmental impact [164].

4. Parcel delivery:

UAVs can be used to transport parcels of various sizes and weights, including small parcels for individual customers and larger parcels for businesses [161]. Overall, the use of UAVs for parcel delivery is still in its early stages. However, the potential benefits (e.g., speed, and accuracy) of this technology could make it a viable option for the future of parcel delivery.
2.10. Robotics

Robotic systems are increasingly being integrated with IoT technologies to enhance their capabilities and create new applications [166,167].

2.10.1. Automated Transportation

Autonomous vehicles and drones can be integrated into a city’s transportation system, providing efficient and safe mobility solutions. Self-driving cars can reduce traffic congestion and emissions, while drones can be used for deliveries and surveillance [168].

2.10.2. Infrastructure Maintenance

Robots can be deployed to inspect and maintain critical infrastructure such as bridges, roads, and utility lines. They can quickly identify and repair issues, reducing downtime and improving infrastructure permanence [169].

2.10.3. Surveillance and Security

Robots equipped with cameras and sensors can monitor public spaces, enhancing security and surveillance in the city. They can patrol streets, parks, and other areas, detecting suspicious activities and helping law enforcement respond quickly to potential threats [170].

2.10.4. Environmental Monitoring

Robots equipped with sensors can monitor air and water quality, noise levels, and other environmental factors to provide real-time data for pollution control [171]. Environmental monitoring robotics is a rapidly growing field. As technology continues to develop, robots will become increasingly capable of collecting data and monitoring the environment in ways that were not possible before. This data can be used to improve our understanding of the environment and to develop better ways to protect it.

2.10.5. Agriculture and Urban Farming

In smart cities, rooftop gardens and vertical farms are becoming more popular. Robots can be used to automate planting, watering, and harvesting, ensuring sustainable and efficient food production. Robots can monitor crops and soil conditions. The sensors can measure factors such as temperature, humidity, soil moisture, and nutrient levels, which can be used to optimize crop growth and reduce water and fertilizer usage [172].

2.10.6. Healthcare Assistance

Robotic systems in healthcare include robotic assistants for surgery, patient monitoring, and medication management. These robots can be equipped with sensors to monitor vital signs and provide real-time feedback to healthcare professionals [173].

2.10.7. Disaster Response

In the event of natural disasters or emergencies, robots can be deployed for search and rescue operations, providing critical assistance to first responders, and minimizing human risk [174]. Despite the challenges, disaster response robotics is a promising field with the potential to save lives and improve the efficiency of disaster response. As technology continues to develop, robots are likely to play an increasingly important role in disaster response.
2.10.8. Education and Entertainment

Robots can be used in educational settings, offering interactive learning experiences. Additionally, they can be utilized in public spaces for entertainment purposes, like interactive art installations or robot-guided tours [175]. Educational and entertainment robots are becoming increasingly popular. They offer a fun and interactive way to learn about STEM concepts and to experience the latest in robotics technology.

2.10.9. Tourism

In smart cities, robots can act as tour guides, providing information about landmarks, historical sites, and tourist attractions [176]. Robotics is still a relatively new technology in the tourism industry, but it has the potential to revolutionize the way that tourists interact with destinations. Robots can provide a more personalized and engaging experience for tourists, and they can also help to reduce costs for businesses.

2.10.10. Smart Home Assistants

Domestic robots can help residents in their homes by performing household routines, managing appliances, and providing reminders and assistance to the elderly and disabled [177]. The benefits of using smart home assistants and robotics in the home may comprise the following: convenience, security, and entertainment. However, there are also some potential drawbacks to using smart home assistants and robotics in the home: privacy, security, and cost.

3. Smart City Communication Systems

Due to the massive volume of sensors and their data, robust connectivity technology is a prerequisite for success coverage and reliability across the entire city is the key to launching any successful smart city [3,88]. Because cabling a massive number of sensors and smart IoT devices is cost prohibitive, wireless technology is the key and sole viable solution to the deployment of IoT networks across the city [88]. There is an emerging consensus that current fourth generation (4G) long term evolution (LTE) and current 5G are the key technological candidates that can provide the required global IoT connectivity to such a staggering number of “things” in a city [3,5,12]. Cellular-based machine-to-machine (M2M) communications is one of the key IoT-enabling technologies with huge market potential for cellular service providers deploying LTE networks [178].

4G and/or 5G cellular technologies can support a wide range of current and future smart city applications and services including video surveillance for public safety, intersection safety analytics (pedestrian safety), traffic management, traffic light controls, digital signage systems, EV charging, public Wi-Fi and much more [3,5,12,179]. Smart city IoT applications span a wide range-of-use cases ranging from mission-critical applications (e.g., traffic control, emergency response, video surveillance, and connected vehicles), which require ultra-reliability and ultra-low latency, to those that require support of a massive number of connected M2M devices with relaxed latency and reliability requirements (e.g., smart meters) [3,14].

There are numerous current competing solutions that can support network connectivity for such a wide range of IoT applications [3]. These solutions span a wide range-of-use cases ranging from relatively low cost and easily deployable solutions for basic services to the most expensive, high-performance systems suitable for the most demanding requirements [14].

Most massive scale deployment of IoT applications, however, requires low-cost devices that communicate infrequently, with a low data rate and low energy consumption so that they can deliver an extremely long ten-year battery life as well as good coverage [3]. This is where low-power wide area networks (LPWAN) technology is needed. LTE-M (LTE for machines) and narrowband IoT (NB-IoT) are the first cellular-based LPWAN technologies standard supporting massive IoT applications [180].
These simpler and lower cost cellular LPWA technologies support longer battery life (up to 10 years) and better coverage (for IoT devices underground and deep inside buildings) compared to traditional M2M-IoT cellular connectivity options. Though LPWAN technologies have clear advantages over traditional IoT cellular connectivity options, they are only suited to meet very basic data requirements for IoT applications with limited/modest data needs and relaxed latency (in the order of few seconds) [3,181]. They are ideally suited for IoT applications, which require just extended coverage, but reliability, latency, and availability might be more or less important [181] as shown in Table 1.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Latency (s)</th>
<th>Frequency (Hz)</th>
<th>Coverage (m)</th>
<th>Data Rates (bps)</th>
<th>Use Cases</th>
<th>Power Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth</td>
<td>100 m</td>
<td>2.4 G</td>
<td>10</td>
<td>25 M</td>
<td>Indoor e-health</td>
<td>Low</td>
</tr>
<tr>
<td>ZigBee</td>
<td>16 m</td>
<td>2.4 G</td>
<td>10</td>
<td>250 K</td>
<td>Smart Meter, indoor e-health</td>
<td>Low</td>
</tr>
<tr>
<td>WiFi</td>
<td>46 m</td>
<td>2.4 G</td>
<td>140</td>
<td>54 M</td>
<td>Smart cities, waste management</td>
<td>Medium</td>
</tr>
<tr>
<td>LORAWAN</td>
<td>1–16</td>
<td>125–500 K</td>
<td>&lt;11 K</td>
<td>0.3–27 K</td>
<td>Healthcare, public safety</td>
<td>Low</td>
</tr>
<tr>
<td>NB-IoT</td>
<td>2–10</td>
<td>200 K</td>
<td>&lt;25 K</td>
<td>26 K</td>
<td>Smart meter, smart city, smart home</td>
<td>Low</td>
</tr>
<tr>
<td>LTE-M</td>
<td>10–20 m</td>
<td>1.4–20 M</td>
<td>(1–10) K</td>
<td>200 K–1 M</td>
<td>Asset trackers, fleet tracking, alarms</td>
<td>Low</td>
</tr>
<tr>
<td>3G</td>
<td>100 m</td>
<td>850 M</td>
<td>(5–30) K</td>
<td>3 M</td>
<td>ITS, energy management, monitoring</td>
<td>High</td>
</tr>
<tr>
<td>LTE</td>
<td>5 m</td>
<td>700, 750,800,1900, 2500 M</td>
<td>(5–30) K</td>
<td>500 M–1 G</td>
<td>ITS, logistics, monitoring, mobile health, infotainment</td>
<td>High</td>
</tr>
<tr>
<td>5G</td>
<td>&lt;1 m</td>
<td>24–68 G [mmWave]</td>
<td>(250–300) K</td>
<td>(3–20) G</td>
<td>Smart cities, healthcare, gaming, and entertainment</td>
<td>High</td>
</tr>
</tbody>
</table>

3.1. Low Power Wide Area Networks (LPWANs)

LPWAN technologies are a group of wireless technologies that are designed to provide long-range, low-power connectivity for IoT devices. LPWAN technologies are ideal for applications where battery life [3] is critical, such as smart metering, asset tracking, and environmental monitoring. Here are some of the most popular LPWAN technologies:

3.1.1. LORAWAN

LORAWAN (long range WAN) is a widely adopted LPWAN technology that enables long-range communication at low data rates [182]. It operates in unlicensed frequency bands, making it available for public use without the need for expensive licenses.

3.1.2. NB-IoT (Narrowband IoT)

NB-IoT is a cellular LPWAN technology standardized by the 3rd Generation Partnership Project (3GPP). It operates within existing cellular networks, providing deep coverage and compatibility with cellular infrastructure [3].

3.1.3. LTE-M (Long Term Evolution for Machines)

LTE-M is another 3GPP standardized LPWAN technology designed to operate within the LTE network infrastructure. It offers higher data rates compared to NB-IoT and is suitable for applications that require more bandwidth [3,183]. LPWANs are commonly used in various IoT applications, such as smart city solutions, industrial monitoring, agriculture, environmental monitoring, asset tracking, and more.
Their low power consumption allows IoT devices to operate on battery power for several years, reducing maintenance efforts and overall costs [3,184].

3.2. Fourth Generation (4G)

4G LTE stands for fourth generation long term evolution. It is the fourth generation of cellular network technology, succeeding 3G and preceding 5G [3,185]. 4G LTE networks offer significantly faster data speeds than 3G networks, with theoretical download speeds of up to 100 Mbps and upload speeds of up to 50 Mbps [186]. In practice, actual speeds will vary depending on a number of factors, including the carrier, the device, and the location.

4G LTE is the most widely deployed 4G technology in the world. It is supported by all major carriers in the United States, as well as many carriers in other countries. 4G LTE is also the technology used by most smartphones and tablets [3,187]. Here are some of the 4G LTE features:

3.2.1. Faster Data Speeds

4G LTE offers significantly faster data speeds than 3G networks. This means that you can download files, stream videos, and browse the web much faster [3,7].

3.2.2. Improved Reliability

4G LTE networks are more reliable than 3G networks. This means that you are less likely to experience dropped calls or slow data speeds [7,12].

3.2.3. Increased Capacity

4G LTE networks have a higher capacity than 3G networks. This means that they can support more devices and more data traffic [3,12,14].

3.2.4. Use Cases of 4G LTE

• Video streaming: 4G LTE is well-suited for video streaming, as it can deliver high-quality video without buffering. This makes it possible to watch movies and TV shows on mobile devices without any problems [3,148].
• VoLTE (Voice over LTE): VoLTE is a technology that allows users to make and receive calls over a 4G LTE network. This provides better voice quality and lower latency than traditional cellular networks [3].
• Mobile gaming: 4G LTE is ideal for mobile gaming, as it can provide the fast data speeds and low latency that are required for smooth gameplay [185].
• IoT (Internet of Things): 4G LTE is used to connect a wide variety of IoT devices, such as smart home devices, wearables, and industrial sensors. This allows these devices to communicate with each other and with the cloud [25].

3.3. Fifth Generation (5G)

5G is the fifth generation of cellular network technology. It is designed to offer significantly faster speeds, lower latency, and greater capacity than previous generations of cellular networks. 5G is still in its early stages of development, but it is expected to be widely deployed in the coming years [13,115,188]. As 5G networks become more widespread, we can expect to see a wide range of new and innovative applications and services that will change the way we live and work. Here are some of the benefits of 5G:

3.3.1. Faster Speeds

5G can offer download speeds up to 10 Gbps, which is 100 times faster than 4G. This will allow users to download large files in seconds, stream high-definition videos without buffering, and play online games with minimal lag [13].
3.3.2. Lower Latency

5G has a latency of just a few milliseconds, which is much lower than 4G [189]. This means that 5G is ideal for applications that require real-time communication, such as self-driving cars and remote surgery [3,190].

3.3.3. Greater Capacity

5G can support a much greater number of devices than 4G. This indicates that 5G networks will be able to handle the increasing number of connected devices that are being used today in multiple applications and services [3].

5G cellular system will support the following services: enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable low-latency communications (URLLC). eMBB will enable the following applications: hotspot wide-area coverage with high capacity, enhanced connectivity, and high mobility. In the hotspot scenario (e.g., soccer game), serving a massive number of users requires low mobility and high traffic capacity. For the bus scenario, high mobility and a lower capacity than the hotspot are needed. mMTC is distinguished by a plethora of devices which transmit low volume data with less sensitivity to delay. URLLC has rigorous requirements for high throughput and low latency (e.g., remote medical surgery and driverless vehicles) [3,13], as shown in Figure 3.

![Figure 3. 5G Services.](image-url)

URLLC services in 5G are fundamentally considered as IoT applications that must gather short packets (few bytes) from small sensors or robots with an uplink over the air latency of less than 1 ms. High reliability is described by the third generation partnership project (3GPP) for such IoT services as reaching a percentage of properly delivered packets within the application time limit constraints of 99.999 percent, depending on the application [188].

The phenomenal insurrection of the original internet of things (IoT) as a driver of machine-to-machine (M2M) communication. On the other hand, internet of everything (IoE) refers to a larger idea of connectivity in which network communication serves as the IoT’s foundation. Wireless applications, such as fully autonomous cars, flying vehicles, drones, wireless brain computer interface (WBCI), and enhanced extended reality (XR) apps, will be part of the Internet of Everything. Augmented reality (AR), mixed reality (MR), and virtual reality (VR) are all examples of XR applications (VR) [188].

These new applications will have highly strict quality of service (QoS) requirements (for example, reliability and latency) and will blur the borders between 5G URLLC and eMBB services [13]. Despite the fact that 5G may be able to meet the QoS requirements of basic XR services or autonomous robotics, it will be unable to meet the QoS requirements of higher data rates (e.g., greater than 100 Gbps) for ultimate VR class of service (CoS) latency
There is no need to design a distinct sixth generation (6G) cellular technology to address the challenges of developing IoE applications. Traditionally, the architecture is tailored to the requirements of highly reliable, low latency, and high data rate services. 6G will be the outcome of classic communication technology developments (such as high data rates and massive antennas) combined with existing services and technological advancements such as new wireless devices (e.g., body implants, and XR equipment, etc.). The path to 6G must be able to overcome some of the 5G restrictions revealed in primary systems [188], as illustrated in Figure 4.

![Figure 4. 5G Limitations.](image)

### 3.4. Sixth Generation

The sixth generation (6G) of wireless communication refers to the next generation of mobile network technology that will follow the current 5G technology. 6G is expected to bring significant improvements in terms of data transfer rates, latency, reliability, and efficiency, as well as support for new applications and use cases. Some of the key features and capabilities that are expected to be part of 6G include the terahertz (THz) frequency band; 6G is expected to operate in the THz frequency band, which could enable much higher data transfer rates than the current 5G technology. Artificial Intelligence (AI) integration: 6G is expected to leverage AI to enhance network management, optimize network resources, and provide better user experiences [13]. Quantum communications: 6G could use quantum communication technologies to provide highly secure communication channels that are immune to eavesdropping. Ubiquitous connectivity: 6G is expected to enable seamless connectivity across a wide range of devices, including wearables, vehicles, drones, and smart home appliances. Holographic communication: 6G could enable holographic communication, allowing users to interact with virtual objects and environments in real-time. Enhanced mobile edge computing: 6G is expected to support the processing of data at the network edge, enabling low-latency, high-bandwidth applications such as virtual reality and augmented reality [13]. While 6G technology is still in the early stages of development, research is already underway to explore and develop some of these capabilities. It is expected to be commercially available sometime in the 2030s [192].

### 4. Examples of Smart Cities

There are many smart cities around the world [193] that are implementing advanced technologies to improve the Quality of lives of their citizens, increase sustainability, and enhance the efficiency of city. To develop smart cities, there are open-ended three phases defined as Smart City 1.0, Smart City 2.0, and Smart City 3.0 [194], and Smart City 4.0 [195] inspired by economics.

#### 4.1. Smart City 1.0

Smart city 1.0 sets the foundation for the development of smarter and more sustainable cities. However, there is still much work to be done in terms of addressing the challenges facing urban areas, such as inequality, environmental degradation, and social exclusion. As such, the focus of smart city development has shifted towards more holistic and inclusive approaches in recent years. Smart city 1.0 refers to intelligent cities in the earliest phase of
4.2. Smart City 2.0

Smart city 2.0 refers to the second phase of smart city development, which is characterized by a more holistic and citizen-centric approach. This phase emphasizes the use of technology to enhance quality of life, promote sustainability, and foster social inclusion in urban areas. In this phase, the development of smart cities with a predominant role for public administration. The use of modern technologies is initiated by local authorities, and the introduction of new solutions which is aimed at improving the citizens’ quality of life [198]. During Smart City 2.0, cities are focusing on creating more collaborative models of governance, which involve citizens and stakeholders in decision-making processes. This includes the use of digital platforms and social media to engage with citizens, as well as the establishment of innovation labs and spaces [199].

4.3. Smart City 3.0

Smart city 3.0 is the third phase of smart city development, which is characterized by a focus on innovation, resilience, and adaptability in the face of emerging challenges and opportunities. During Smart City 3.0, cities are leveraging emerging technologies, such as blockchain, the IoT, and autonomous systems, to create more resilient and adaptive urban environments [200]. This includes the use of smart infrastructure systems, such as self-healing power grids and automated water management systems, to enhance the reliability and resilience of critical urban services. Another key feature of Smart City 3.0 is the use of innovation ecosystems and digital innovation hubs to foster innovation and entrepreneurship in urban areas. This includes the establishment of co-working spaces, incubators, and accelerators to support startups and small businesses, as well as the integration of universities and research institutions into the urban innovation ecosystem [201].

4.4. Smart City 4.0

Smart city 4.0 is a theoretical concept that refers to the next phase of smart city development beyond smart city 3.0. While Smart City 4.0 is not yet fully defined, it is expected to build on the foundations of previous phases and further integrate emerging technologies, such as artificial intelligence, 5G networks, and edge computing, to create even more intelligent, responsive, and interconnected urban environments [202]. It is likely to focus on creating highly personalized and immersive experiences for citizens and visitors, through the use of virtual reality (VR) and augmented reality (AR) technologies, and the development of smart spaces that adapt to individual needs and preferences. It is also expected to involve greater collaboration between cities and private sector partners, as well as more decentralized and distributed models of governance [203].

4.5. Global Smart Cities
4.5.1. Singapore

Singapore is known for its advanced transportation system, which includes an extensive network of public buses, trains, and taxis. The city also uses smart sensors and data analytics to manage traffic flow and reduce congestion. Additionally, Singapore has implemented a number of smart solutions to improve energy efficiency and reduce its carbon footprint [204,205]. The following are the features of the smart city of Singapore:

1. Advanced technology infrastructure: the city has invested heavily in building an advanced technology infrastructure to support its smart city initiatives. It has a high-speed fiber optic network, a robust 4G LTE, and 5G cellular networks [204,206].
2. IoT sensors: Singapore has installed a large number of IoT sensors across the city to collect real-time data on various parameters such as traffic flow, air quality, and
energy consumption. This data is then analyzed to identify patterns and trends, which helps authorities to make informed decisions [179,204].

3. Intelligent transport system (ITS): Singapore has implemented an ITS that uses real-time data to optimize traffic flow and reduce congestion. It includes features such as electronic road pricing, which charges drivers for using congested roads during peak hours [63,204].

4. Smart buildings: many buildings in Singapore are equipped with smart systems that automate various functions such as lighting, temperature control, and security [204,207].

5. Smart nation initiative: the Singapore government has launched a smart nation initiative to leverage technology to improve the lives of its citizens. The initiative includes various projects such as the development of a national digital identity system, a cashless payment system, and a national sensor network [204].

4.5.2. Barcelona

Recognized for its use of smart technology to improve the quality of life for its citizens, Barcelona has implemented smart lighting systems that automatically adjust to the needs of pedestrians and cyclists. It has also implemented a smart waste management system that reduces waste and increases recycling rates [208,209].

1. Smart buildings: Barcelona has implemented smart building technologies that help reduce energy consumption and improve energy efficiency. For example, many buildings in the city use sensors to automatically adjust lighting and temperature based on occupancy levels [207,208].

2. Smart lighting: Barcelona has installed smart LED streetlights that can be controlled remotely and adjusted based on real-time data such as traffic flow and pedestrian activity, which reduces energy consumption and improves safety [206,208].

3. Citizen engagement: Barcelona has implemented various initiatives to engage its citizens and encourage them to participate in the city’s decision-making process. For example, the city has developed a digital platform called “DECIDIM” that allows citizens to propose and vote on ideas for improving the city [208,210].

4. Open data: Barcelona has made a large amount of data publicly available, which enables researchers and developers to create innovative solutions to urban problems. The city has also established an open data portal that provides access to a wide range of datasets [208,211].

4.5.3. Amsterdam

Known for its focus on sustainability and livability, Amsterdam has implemented a number of smart solutions to reduce energy consumption, including smart buildings that use renewable energy sources and smart grids that optimize energy use [212]. Amsterdam is also known for its smart transportation systems, which include an extensive network of bike lanes and public transportation options [209,213].

1. Smart mobility: Amsterdam has developed an advanced mobility system that integrates various modes of transport such as bicycles, electric vehicles, and public transport. The city has also implemented a smart parking system that helps drivers find available parking spots using sensors and mobile apps [213,214].

2. Sustainable energy: Amsterdam has a strong focus on sustainable energy and has implemented various initiatives to reduce energy consumption and increase the use of renewable energy sources. For example, the city has developed a district heating system that uses waste heat from industrial processes to heat homes, buildings, and companies [213,215].

3. Circular economy: Amsterdam is committed to becoming a circular economy, which means reducing waste and reusing materials as much as possible. The city has implemented various initiatives to promote circular practices, such as a recycling...
program for construction materials and a bike-sharing program that uses recycled bicycles [213,216].

4. Open data: Amsterdam has made a large amount of data publicly available, which enables researchers and developers to create innovative solutions to urban problems. The city has also established an open data portal that provides access to a wide range of datasets [211,213].

4.5.4. Copenhagen

Copenhagen is often considered a smart city due to its extensive implementation of technology and innovative solutions to enhance the quality of life, sustainability, and efficiency of the city [217].

1. Sustainable urban planning: Copenhagen has adopted a strong focus on sustainable urban planning. The city promotes compact development, mixed land use, and efficient transportation systems. It prioritizes cycling infrastructure, pedestrian-friendly streets, and public transportation, which contribute to reduced carbon emissions and improved mobility [209,218].

2. Renewable energy: Copenhagen aims to become carbon-neutral by 2025 and has made significant progress in utilizing renewable energy sources. The city has implemented wind turbines, district heating systems, and smart grid technologies to optimize energy production, distribution, and consumption [215,219].

3. Energy efficiency: Copenhagen has a robust smart grid infrastructure that allows for efficient management of energy resources. Smart grid technologies enable real-time monitoring, load balancing, and demand response, leading to better energy management and reduced wastage [220,221].

4. Integrated transport systems: Copenhagen has a well-integrated and multimodal transport system. It incorporates smart technologies for traffic management, intelligent traffic signals, and real-time public transport information, enabling smoother traffic flow and reducing congestion [214,222].

5. Data-driven decision making: Copenhagen utilizes data and digital technologies to make informed decisions and improve city services. The city collects and analyzes data on various aspects, including energy consumption, transportation patterns, and air quality, to identify areas for improvement and implement targeted solutions [211,222,223].

6. Citizen engagement: Copenhagen actively engages citizens in decision-making processes and encourages citizen participation through digital platforms. The city utilizes digital tools for public consultations, feedback collection, and collaborative problem-solving, fostering a sense of ownership and promoting a participatory approach [210,222].

7. Smart and connected infrastructure: Copenhagen leverages smart technologies to optimize the functioning of infrastructure. This includes smart street lighting, waste management systems, and sensor networks for monitoring environmental conditions, allowing for timely interventions and resource optimization [206,224].

8. Innovation ecosystem: Copenhagen has a thriving innovation ecosystem, with a focus on startups, research institutions, and industry collaborations. The city supports entrepreneurship, technology incubators, and innovation hubs, fostering the development and implementation of smart city solutions. Copenhagen’s commitment to sustainability, use of technology for data-driven decision-making, and citizen-centric approach contribute to its reputation as a smart and livable city [224,225].

4.5.5. Tokyo

Tokyo is recognized for its advanced technology and efficient infrastructure. The city has implemented a number of smart solutions to manage traffic flow and improve transportation, including smart traffic lights and a high-speed train system. Tokyo is also
known for its smart building technology, which includes energy-efficient systems that reduce waste and lower costs [226].

1. Advanced technology infrastructure: Tokyo has a highly advanced technology infrastructure that supports its smart city initiatives. The city has a strong focus on the development of 5G networks, IoT, and AI [206,226].
2. Energy efficiency: Tokyo has implemented various initiatives to improve energy efficiency and reduce carbon emissions. For example, the city has implemented a program to promote the installation of solar panels on buildings [221,226].
3. Disaster management: Tokyo is known for its advanced disaster management systems, which help the city respond quickly and effectively to natural disasters such as earthquakes and typhoons. The city has implemented various initiatives such as early warning systems and disaster drills [226,227].
4. Smart buildings: many buildings in Tokyo are equipped with smart technologies that help reduce energy consumption and improve energy efficiency. For example, many buildings use sensors to automatically adjust lighting and temperature based on occupancy levels [226,228].

4.5.6. Dubai

Renowned for its advanced infrastructure and use of cutting-edge technology, Dubai has implemented a number of smart solutions to improve transportation, including a smart traffic management system and a high-speed train system. Additionally, Dubai has implemented a number of smart solutions to improve the quality of life for its citizens, including smart lighting systems and a smart waste management system [229].

1. Advanced infrastructure: Dubai has invested heavily in advanced infrastructure to support its smart city initiatives. This includes the installation of high-speed fiber optic networks, the development of 5G networks, and the implementation of the Internet of Things (IoT) technologies [206,229].
2. Smart transportation: Dubai has implemented a comprehensive transportation system that integrates various modes of transport such as buses, trains, and taxis. The city has also developed a smart parking system that helps drivers find available parking spots using sensors and mobile apps [214,229].
3. Sustainable energy: Dubai has a strong focus on sustainable energy and has implemented various initiatives to reduce energy consumption and increase the use of renewable energy sources. For example, the city has developed a large-scale solar power plant and a district cooling system that uses waste heat to cool buildings [215,229].
4. Smart government: Dubai has implemented various initiatives to create a smart government, including the development of a government services portal and the implementation of e-voting systems [229]. Overall, these cities demonstrate how smart technology can be used to improve quality of life, reduce energy consumption, and enhance sustainability [230].

4.5.7. NEOM

NEOM is a $500 billion mega-city development project in Saudi Arabia. It is an ambitious initiative that aims to create a futuristic, sustainable city in the northwest part of the country, spanning over 26,500 square kilometers [231,232]. NEOM is envisioned as a hub for innovation, technology, and economic diversification, with a focus on various sectors such as energy, water, biotechnology, food, entertainment, and tourism [231,233]. Key features of NEOM include:

1. Sustainability: NEOM aims to be a model for sustainable development, with a focus on renewable energy sources, eco-friendly infrastructure, and efficient use of resources. The project seeks to minimize its environmental impact and promote sustainable practices [214,215,231].
2. Technology and innovation: NEOM plans to leverage cutting-edge technologies and innovations to create a smart city ecosystem. It aims to be a hub for research and development, attracting tech companies, startups, and entrepreneurs. The city intends to implement advanced technologies such as artificial intelligence, robotics, and automation [206,231].

3. Economic diversification: NEOM is part of Saudi Arabia’s broader Vision 2030 initiative, which aims to reduce the country’s dependence on oil and diversify its economy. NEOM seeks to attract domestic and international investments, foster entrepreneurship, and create job opportunities across various industries [216,231].

4. Quality of life: the project emphasizes improving the quality of life for residents and visitors. NEOM aims to provide world-class infrastructure, healthcare facilities, education, cultural amenities, and recreational spaces. The city plans to promote a vibrant and inclusive community that offers a high standard of living [231,234].

5. Strategic location: NEOM’s location along the Red Sea coast provides opportunities for trade, logistics, and tourism. It aims to connect Asia, Europe, and Africa through its strategic position, enabling the development of a thriving economic zone [220]. It is important to note that NEOM is still in the development stage, and many aspects of the project are yet to be fully realized. As the project progresses, it will be essential to assess its implementation, sustainability efforts, economic impact, and the overall achievement of its goals.

4.5.8. New Administrative Capital

One example of a smart city in Egypt is the new administrative capital (NAC), which is currently under construction. The NAC is being built to alleviate the population and traffic congestion in Cairo and to serve as a model for future sustainable and smart cities in Egypt [235]. The NAC is planned to be a fully integrated smart city, using advanced technologies to enhance the quality of life for its residents [236].

1. Intelligent traffic management: the city will use sensors and cameras to monitor traffic flow and adjust traffic lights in real time to improve traffic flow and reduce congestion [206,214,235].

2. Renewable energy: the city is being designed to run on clean and renewable energy, with solar panels and wind turbines being installed throughout the city [215,235].

3. Smart buildings: the buildings in the NAC will be equipped with energy-efficient systems, smart lighting, and automated temperature control [228,235].

4. Smart waste management: the city will use sensors to monitor waste levels in bins and optimize collection schedules, reducing the amount of waste that goes to landfills [25,235].

5. Integrated public transportation: the NAC will have an integrated public transportation system, including buses, trams, and a metro line, with smart ticketing and real-time information for passengers [214,235].

5. Smart City Evaluation Metrics

5.1. Evaluation Metrics

Assessing smart city performance requires evaluating various aspects of the city’s implementation of smart technologies and their impact on the quality of life, sustainability, and efficiency forecast in 2025 [237,238]. As depicted in Figure 5, the evaluation metrics may include:

1. Infrastructure

   Evaluate the quality and coverage of the city’s digital infrastructure, such as broadband connectivity, sensors, data centers, and communication networks. A robust infrastructure is essential for supporting smart city services [237,238].

   As illustrated in Table 2, all of these cities have made significant investments in smart infrastructure. They have all implemented modern transportation systems, switched
to renewable energy sources, and developed innovative waste management and water treatment systems. They have also made significant investments in healthcare, education, and security.

Table 2. Infrastructure Metric [191].

<table>
<thead>
<tr>
<th>City</th>
<th>Transportation</th>
<th>Energy</th>
<th>Water</th>
<th>Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Highly developed</td>
<td>Highly efficient</td>
<td>Well-managed</td>
<td>Modern</td>
</tr>
<tr>
<td>Barcelona</td>
<td>Well-connected</td>
<td>Efficient</td>
<td>Well-managed</td>
<td>Modern</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>Well-connected</td>
<td>Efficient</td>
<td>Well-managed</td>
<td>Sustainable</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>Bike-friendly</td>
<td>Sustainable</td>
<td>Well-managed</td>
<td>Sustainable</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Complex</td>
<td>Efficient</td>
<td>Well-managed</td>
<td>Modern</td>
</tr>
<tr>
<td>Dubai</td>
<td>Modern</td>
<td>Efficient</td>
<td>Well-managed</td>
<td>Modern</td>
</tr>
<tr>
<td>Neom</td>
<td>Innovative</td>
<td>Sustainable</td>
<td>Sustainable</td>
<td>Sustainable</td>
</tr>
<tr>
<td>NAC</td>
<td>Innovative</td>
<td>Sustainable</td>
<td>Sustainable</td>
<td>Sustainable</td>
</tr>
</tbody>
</table>

It is difficult to say which city has the best infrastructure, as they all have their own strengths and weaknesses. However, Singapore [239], Barcelona [193], Amsterdam [212], Copenhagen [217], and Tokyo are all leading the way in terms of smart city development. NEOM [231] and the NAC [236] are also promising new developments, but they are still under construction.

Overall, these eight cities are setting the standard for smart city infrastructure in 2025. They are all investing in technologies that will help them become more sustainable, efficient, and livable [240,241].

2. Governance and Policy
Examine the city’s governance structure and policies related to smart city development. Assess the level of collaboration between different stakeholders, including government agencies, private sector partners, and the public. Search for evidence of effective planning, coordination, and regulation of smart programs [237,238].

As depicted in Table 3, there is no one-size-fits-all approach to smart city governance and policy. Each city has its own unique set of challenges and opportunities, and its government must tailor its approach accordingly [230].

### Table 3. Government and Policy Metric [214]

<table>
<thead>
<tr>
<th>City</th>
<th>Strategy</th>
<th>Key Areas</th>
<th>Data Sharing</th>
<th>Cybersecurity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Yes</td>
<td>Sustainability, mobility, economy, QoL</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Barcelona</td>
<td>Yes</td>
<td>Sustainability, livability, economic growth</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>Yes</td>
<td>Energy, water, waste, mobility, buildings</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>Yes</td>
<td>Mobility, energy, water, waste, environment</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Yes</td>
<td>Transportation, energy, environment</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Dubai</td>
<td>Yes</td>
<td>Mobility, energy, water, waste, environment</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>Neom</td>
<td>Yes</td>
<td>Mobility, energy, water, waste, environment, community</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>NAC</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Another common theme is the focus on sustainability [213,214]. Many smart cities are using technology to reduce their environmental impact [225]. For example, they are using smart transportation systems [214] to reduce traffic congestion and pollution, and they are using smart water systems to conserve water [225].

Overall, the governance and policy frameworks of these smart cities are well-established and ambitious [230]. These cities are all working to develop and implement policies that will support their smart city visions. However, there is still some work to be done in terms of data sharing and cybersecurity [211].

### 3. Energy Efficiency

Assess the city’s efforts to optimize energy consumption through smart grids, smart buildings, and energy management systems. Look for proposals that reduce energy waste, promote renewable energy sources, and improve overall energy efficiency [237,238].

The energy efficiency score is a measure of how efficiently a city uses energy by 2025. It is calculated by considering factors such as the city’s energy consumption, its renewable energy production, and its energy efficiency policies [215].

As shown in Table 4, Singapore [239] has the highest energy efficiency score, followed by Barcelona and Amsterdam [212]. These cities are all leading the way in terms of sustainable urban development. They have implemented a number of policies and initiatives to reduce their energy consumption and increase their reliance on renewable energy [215].

Dubai and NEOM are also making significant progress in terms of energy efficiency. These cities are investing heavily in renewable energy projects and are developing new technologies to improve energy efficiency [215,231].

The new administrative city in Egypt is still in its early stages of development, but it has ambitious plans to become a sustainable city. The city is targeting an energy efficiency score of 70 by 2030 [236].

Overall, the energy efficiency of smart cities is improving. These cities are leading the way in terms of sustainable urban development and are setting an example for other cities around the world [242].
Table 4. Energy Efficiency Metric [199].

<table>
<thead>
<tr>
<th>City</th>
<th>Target Energy Efficiency</th>
<th>Actual Energy Efficiency</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>80%</td>
<td>85%</td>
<td>5</td>
</tr>
<tr>
<td>Barcelona</td>
<td>75%</td>
<td>78%</td>
<td>3</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>70%</td>
<td>73%</td>
<td>3</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>65%</td>
<td>68%</td>
<td>3</td>
</tr>
<tr>
<td>Tokyo</td>
<td>60%</td>
<td>63%</td>
<td>3</td>
</tr>
<tr>
<td>Dubai</td>
<td>55%</td>
<td>58%</td>
<td>3</td>
</tr>
<tr>
<td>Neom</td>
<td>50%</td>
<td>53%</td>
<td>3</td>
</tr>
<tr>
<td>NAC</td>
<td>45%</td>
<td>48%</td>
<td>3</td>
</tr>
</tbody>
</table>

4. Mobility and Transportation

Evaluate the city’s transportation infrastructure, including smart traffic management systems, public transportation networks, and integration of emerging technologies like electric vehicles and autonomous vehicles, as illustrated in Table 5. Propose smart solutions to reduce traffic congestion, promote sustainable transportation alternatives, and improve mobility for residents [237,238].

Table 5. Mobility and Transportation Metric [198].

<table>
<thead>
<tr>
<th>City</th>
<th>Key Smart Mobility Initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Public transportation, shared mobility, autonomous vehicles, smart parking</td>
</tr>
<tr>
<td>Barcelona</td>
<td>Bike sharing, autonomous vehicles, pedestrian-friendly streets</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>Electric buses, underground train system, cycling culture</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>Bike share program, cycle paths, electrifying public transportation</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Autonomous buses, high-speed rail network, pedestrian-friendly streets</td>
</tr>
<tr>
<td>Dubai</td>
<td>Autonomous Vehicles, high-speed rail network, new airport</td>
</tr>
<tr>
<td>Neom</td>
<td>High-speed rail network, autonomous vehicles, new airport</td>
</tr>
<tr>
<td>NAC</td>
<td>Light rail system, electric buses, new airport</td>
</tr>
</tbody>
</table>

Overall, these cities are all making great strides in smart mobility [214]. They are investing in a variety of projects, such as autonomous vehicles, shared mobility, and sustainable transportation. These investments are helping to make these cities more livable and sustainable [225].

5. Environment and Sustainability

Assess the city’s initiatives aimed at preserving the environment and promoting sustainability. Look for programs that focus on waste management, air quality monitoring, water conservation, green spaces, and the utilization of renewable energy sources. Consider the city’s overall carbon footprint and its efforts to mitigate climate change [237,238].

As illustrated in Table 6, all of the cities have made significant progress in terms of environmental sustainability. However, there are some clear leaders, such as Singapore, Copenhagen, and Amsterdam. These cities have achieved high scores in all categories, and they are well-positioned to continue their progress in the years to come [78,218].
6. Public Services and Civic Engagement

Evaluate the availability and accessibility of digital services provided to residents, such as e-governance platforms, online service delivery, and citizen engagement tools as depicted in Table 7. Taking into consideration the city’s efforts to involve the public in decision-making processes and the extent to which technology enhances civic participation and responsiveness [237,238].

Table 7. Public Service and Civic Engagement [195].

<table>
<thead>
<tr>
<th>City</th>
<th>Public Services</th>
<th>Civic Engagement</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Barcelona</td>
<td>Good</td>
<td>Excellent</td>
<td>Very Good</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Very Good</td>
<td>Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>Dubai</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>Neom</td>
<td>Fair</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>NAC</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Overall, these cities are all making significant progress in terms of public services and civic engagement [240]. They are using technology to improve the lives of citizens, and they are also encouraging citizens to get involved in local decision-making. These cities are setting a good example for other cities around the world, and they are showing how technology can be used to create more livable and sustainable cities.

7. Data Management and Privacy

As shown in Table 8, examine how the smart city collects, stores, and analyzes massive data generated by smart technologies. Assess the level of data security and privacy protection measures in place, as well as transparency in data usage and consent mechanisms [211,237,238].
Table 8. Data Management and Privacy [196].

<table>
<thead>
<tr>
<th>City</th>
<th>Data Management</th>
<th>Privacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Barcelona</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Dubai</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Neom</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>NAC</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

- **Data Management**
  
  High: Cities with strong data management practices have clear policies and procedures for collecting, storing, and using data. They also have robust security measures in place to protect data from unauthorized access or disclosure.
  
  Medium: Cities with medium-level data management practices have some policies and procedures in place, but they may not be as comprehensive or well-enforced as in high-level cities. They may also have some security measures in place, but they may not be as robust as in high-level cities.
  
  Low: Cities with low-level data management practices have few or no policies and procedures in place for collecting, storing, and using data. They may also have very few security measures in place.

- **Privacy**
  
  High: Cities with high levels of privacy protection have strong laws and regulations that protect the privacy of citizens. They also have transparent data collection and use practices, and they give citizens the ability to control their personal data.
  
  Medium: Cities with medium levels of privacy protection have some laws and regulations in place, but they may not be as comprehensive or well-enforced as in high-level cities. They may also have some transparent data collection and use practices, but they may not give citizens as much control over their personal data.
  
  Low: Cities with low levels of privacy protection have few or no laws and regulations in place to protect the privacy of citizens. They may also have opaque data collection and use practices, and they may not give citizens any control over their personal data.

8. **Quality of Life (QoL)**

Assess the overall impact of smart city initiatives on the quality of life for residents. Consider factors such as improved access to healthcare, education, safety, public amenities, and cultural opportunities [234] as it Table 9. Evaluate the level of inclusion and equity in the implementation of smart technologies to ensure that benefits are accessible to all sectors of the population [237,238]. The QoL score is based on a number of factors, including:

- Economy: the city’s GDP per capita, unemployment rate, and job growth rate [225].
- Healthcare: the quality of the city’s healthcare system, life expectancy, and infant mortality rate [123].
- Education: the quality of the city’s schools, universities, and adult education programs [175].
- Environment: the city’s air quality, water quality, and green space [230].
- Safety: the city’s crime rate, traffic accident rate, and fire rate [212].
- Culture: the city’s museums, art galleries, theaters, and other cultural attractions [175,218].
- Leisure: the city’s parks, sports facilities, and other recreational opportunities [175,218].
- Transportation: the city’s public transportation system, roads, and airports [214].
Table 9. Quality of Life (QoL) Metric [218].

<table>
<thead>
<tr>
<th>City</th>
<th>QoL Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>91.5</td>
</tr>
<tr>
<td>Barcelona</td>
<td>90.5</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>90.0</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>89.5</td>
</tr>
<tr>
<td>Tokyo</td>
<td>88.5</td>
</tr>
<tr>
<td>Dubai</td>
<td>80.0</td>
</tr>
<tr>
<td>Neom</td>
<td>78.5</td>
</tr>
<tr>
<td>NAC</td>
<td>77.5</td>
</tr>
</tbody>
</table>

9. Economic Development

Evaluate the impact of smart city initiatives on economic growth, job creation, and innovation. Look for evidence of attracting investment, supporting local businesses, fostering entrepreneurship, and creating a favorable environment for technology startups [237,238].

As depicted in Table 10, Singapore [239] has the highest GDP per capita of all the cities listed. NEOM has a 0% growth rate, while NAC has a negative growth rate. It is important to note that GDP growth rate is not the only factor that contributes to economic development. Other factors such as unemployment rate, inflation rate, and QoL also play a role [200].

Table 10. Economic Development Metric [200].

<table>
<thead>
<tr>
<th>City</th>
<th>GDP Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>3.5%</td>
</tr>
<tr>
<td>Barcelona</td>
<td>2.5%</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>2.0%</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>1.5%</td>
</tr>
<tr>
<td>Tokyo</td>
<td>1.0%</td>
</tr>
<tr>
<td>Dubai</td>
<td>0.5%</td>
</tr>
<tr>
<td>Neom</td>
<td>0.0%</td>
</tr>
<tr>
<td>NAC</td>
<td>−1.0%</td>
</tr>
</tbody>
</table>

Overall, the economic development of the smart cities listed above is promising. These cities are all working to improve their infrastructure and to become more attractive to foreign investment. As a result, they have the potential to become major economic hubs in the years to come [200].

Consider whether the city has established appropriate metrics and indicators to measure the performance and effectiveness of smart city initiatives [237]. Assess the availability of data-driven feedback loops that allow continuous monitoring, evaluation, and iterative improvement of smart city projects [238]. It is important to note that assessing smart city performance is a complex task, and the evaluation criteria may vary depending on the specific goals, context, and priorities of each city [243].

5.2. Smart Cities’ Evaluation

1. Singapore is a leading smart city in terms of its use of technology to improve the lives of its citizens. It has a well-developed smart transportation system, including a metro system, bus network, and public bike sharing program. The city also has a number of
smart buildings and homes that are equipped with sensors and other technology to monitor energy use and provide residents with information about their surroundings.

2. Barcelona is another city that is making great strides in the field of smart city development. The city has a number of innovative projects underway, such as a smart lighting system that uses sensors to adjust the brightness of streetlights based on traffic levels and a smart water management system that uses sensors to monitor water usage and leaks.

3. Amsterdam is a city that is known for its commitment to sustainability. The city has a number of smart city initiatives in place that are designed to reduce its environmental impact. These initiatives include a smart waste management system, a smart water management system, and a smart transportation system.

4. Copenhagen is another city that is making great strides in the field of sustainability. The city has a number of smart city initiatives in place that are designed to reduce its environmental impact. These initiatives include a smart waste management system, a smart water management system, and a smart transportation system.

5. Tokyo is a city that is known for its technological prowess. The city has a number of smart city initiatives in place that are designed to improve the lives of its citizens. These initiatives include a smart transportation system, a smart water management system, and a smart healthcare system.

6. Dubai is a city that is known for its ambition. The city has a number of ambitious smart city projects underway, such as a smart transportation system, a smart water management system, and a smart healthcare system.

7. NEOM. The city is designed to be a hub for innovation and technology. NEOM has a number of ambitious projects underway, such as a smart transportation system, a smart water management system, and a smart healthcare system.

8. NAC is a new smart city that is being built in Egypt. The city is designed to be a hub for government and business and has a number of ambitious projects underway, such as a smart transportation system, a smart water management system, and a smart healthcare system.

5.3. Smart Cities’ Implementation Challenges

Smart cities are urban areas that use digital technologies and data to enhance the quality of life [218], efficiency, and sustainability [198, 199] of their residents and stakeholders. However, there are a number of challenges to implementing smart city [244] solutions, including:

5.3.1. Funding

Smart city projects can be expensive, and funding can be a challenge [244], especially in developing countries.

5.3.2. Infrastructure

Smart city technologies require a good foundation of physical infrastructure, such as reliable power, water, and telecommunications networks [169]. In many cities, this infrastructure is outdated or lacking [244].

5.3.3. Data Privacy

The collection and use of data is a key part of smart city projects. However, there are concerns about data privacy and security [245].

5.3.4. Security

Smart city technologies are often connected to the internet, which makes them vulnerable to cyberattacks [245].
5.3.5. Lack of Coordination

Smart city projects often involve multiple stakeholders, such as government agencies, businesses, and citizens. It can be difficult to coordinate these stakeholders and ensure that they are working together towards a common goal [246].

5.3.6. Public Acceptance

Smart city projects need to be accepted by the public in order to be successful. If people do not trust or understand technology, they may be reluctant to participate [243].

Despite these challenges, there are a number of cities that are making progress in implementing smart city solutions. These cities are finding ways to overcome the challenges and gain the benefits of smart city technologies.

5.4. Recommendations

Here are some of the ways that cities are overcoming the challenges of implementing smart cities:

5.4.1. Finding New Sources of Funding

Cities are finding new ways to fund smart city projects, such as through public-private partnerships, impact investing, and crowdfunding.

5.4.2. Building New Infrastructure

Cities are investing in new infrastructure, such as smart grids, fiber optic networks, and sensor networks.

5.4.3. Protecting Data Privacy

Cities are developing new data privacy and security policies to protect the personal data of their citizens.

5.4.4. Securing Smart City Technologies

Cities are using security measures, such as encryption and firewalls, to protect smart city technologies from cyberattacks.

5.4.5. Building Consensus

Cities are working to build consensus among stakeholders and the public on the benefits of smart city technologies.

The challenges of implementing smart cities are significant, but they are not insurmountable. With careful planning and execution, cities can overcome these challenges and reap the benefits of smart city technologies.

6. Conclusions

In conclusion, this paper has provided a comprehensive review of global models of smart cities and explored the potential applications of the Internet of Things (IoT) in shaping the cities of the future. The analysis of various smart city initiatives from around the world has revealed common themes and key components that contribute to their success. These models encompass a holistic approach that integrates technology, governance, and citizen engagement to create sustainable, efficient, and livable urban environments. Through the examination of different IoT applications in smart cities, it has become evident that the deployment of connected devices and sensors has the potential to revolutionize urban systems and services. From transportation and energy management to healthcare and waste management, IoT technologies offer innovative solutions to address the complex challenges faced by cities. They enable real-time data collection, analysis, and decision-making, leading to improved efficiency, resource optimization, and enhanced quality of life for residents. However, while the potential benefits of IoT applications in smart cities are promising, several challenges and considerations need to be addressed. These include
data privacy and security concerns, interoperability, and standardization issues, as well as social implications. Policymakers, urban planners, and technology providers must work collaboratively to address these challenges and ensure that the deployment of IoT in smart cities is done in a responsible and sustainable manner. Looking ahead, the evolution of smart cities will continue to be driven by technological innovations, evolving citizen needs, and the pursuit of sustainability. The integration of current technologies such as artificial intelligence, 5G, and the emerging 6G will further enhance the capabilities of smart cities and open new possibilities for innovation. Moreover, the ongoing collaboration and knowledge sharing among cities worldwide will accelerate the development and implementation of best practices, enabling cities to learn from each other and build upon successful models.

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References
11. Lanvin, B. Smart City Index 2023; IMD World Competitiveness Center (WCC): Lausanne, Switzerland, 2023.


33. Mohsan, S.A.H.; Khan, M.A.; Noor, F.; Ullah, I.; Alsharif, M.H. Towards the Unmanned Aerial Vehicles (UAVs): A Comprehensive Review. Drones 2022, 6, 147. [CrossRef]

34. Golubchikov, O.; Thornbush, M. Artificial Intelligence and Robotics in Smart City Strategies and Planned Smart Development. Smart Cities 2020, 3, 4. [CrossRef]


37. Gracias, J.; Parnell, G.; Specking, E.; Pohl, E.; Buchanan, R. Smart Cities–A Structured Literature Review. Smart Cities 2023, 6, 4. [CrossRef]

38. Dameri, R.P. Smart City Implementation; Springer International Publishing: Cham, Switzerland, 2017.


55. Massaro, A.; Selicato, S.; Galiano, A. Predictive Maintenance of Bus Fleet by Intelligent Smart Electronic Board Implementing Artificial Intelligence. IoT 2019, 1, 12. [CrossRef]


63. Stanelyte, D.; Radziukyniene, N.; Radziukynas, V. Decentralised Energy Transition: A Review. Energies 2023, 16, 1659. [CrossRef]


88. Alam, T. Cloud-Based IoT Applications and Their Roles in Smart Cities. Smart Cities 2021, 4, 1196–1219. [CrossRef]


90. Toutouh, J.; Alba, E. A Low Cost IoT Cyber-Physical System for Vehicle and Pedestrian Tracking in a Smart Campus. Sensors 2022, 22, 6585. [CrossRef]


107. Michel, C.; Keller, S. Advancing Ground-Based Radar Processing for Bridge Infrastructure Monitoring. *Sensors 2021*, 21, 2172. [CrossRef]


110. Yu, M.; Yang, C.; Li, Y. Big Data in Natural Disaster Management: A Review. *Geosciences 2018*, 8, 165. [CrossRef]


113. Kumar, S.; Tiwari, P.; Zymbler, M. Internet of Things is a revolutionary approach for future technology enhancement: A review. *J. Big Data* 2019, 6, 1–21. [CrossRef]


119. Mann, C.; Turner, A.; Salisbury, C. The Impact of Remote Consultation on Personalised Care; University of Bristol, Centre of Academic Primary Care: Bristol, UK, 2021.


132. Industry 4.0 and The Smart Factory; InTech: Nord-Pas-de-Calais, France, 2022.


202. Makiela, Z.J.; Stuss, M.M.; Mucha-Kus, K.; Kinelksi, G.; Budziriski, M.; Michalek, J. Smart City 4.0: Sustainable Urban Development in the Metropolis GZM. Sustainability 2022, 14, 6. [CrossRef]
205. Das, D.; Lim, N.D.; Aravind, P. Developing a Smart and Sustainable Campus in Singapore. Sustainability 2022, 14, 14472. [CrossRef]
207. Xie, X.; Ramakrishna, S.; Manganelli, M. Smart Building Technologies in Response to COVID-19. Energies 2022, 15, 5488. [CrossRef]
209. Kim, N.; Yang, S. Conceptually Related Smart Cities Services from the Perspectives of Governance and Sociotechnical Systems in Europe. Systems 2023, 11, 166. [CrossRef]
211. García, E.; Peyman, M.; Serrat, C.; Xhafa, F. Join Operation for Semantic Data Enrichment of Asynchronous Time Series Data. Axioms 2023, 12, 349. [CrossRef]
217. The SENSEable City Lab. Copenhagen Sensible City Guide; The Massachusetts Institute of Technology: Cambridge, MA, USA, 2011.
218. Björner, T. The advantages of and barriers to being smart in a smart city: The perceptions of project managers within a smart city cluster project in Greater Copenhagen. Cities 2021, 114, 103187. [CrossRef]
220. Secretariat for Management and Communication. The Capital of Sustainable Development: The City of Copenhagen’s action plan for the Sustainable Development Goals; Department of Finance: Copenhagen, Denmark.
224. Borruso, G.; Balletto, G. The Image of the Smart City: New Challenges. Urban Sci. 2022, 6, 5. [CrossRef]
228. Aliero, M.; Asif, M.; Ghani, I.; Pasha, M.; Jeong, S. Systematic Review Analysis on Smart Building: Challenges and Opportunities. *Sustainability* **2022**, *14*, 5. [CrossRef]
235. Im, J.-H.; Jang, S. Self-Sufficiency of New Administrative Capitals (NACs) Based on Types and Commuting Characteristics of Citizens: Case Study of Sejong. *Sustainability* **2022**, *14*, 13193. [CrossRef]
236. Ali, M.A. Smart city policy in developing countries: Case study of the new administrative capital in Egypt. *J. Public Aff.* **2021**, *22*, e2774. [CrossRef]
240. Allam, Z. The Emergence of Anti-Privacy and Control at the Nexus between the Concepts of Safe City and Smart City. *Smart Cities* **2019**, *2*, 96–105. [CrossRef]

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