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Review

An Investigation of the Policies and Crucial Sectors of Smart Cities Based on IoT Application

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Abstract: As smart cities (SCs) emerge, the Internet of Things (IoT) is able to simplify more sophisticated and ubiquitous applications employed within these cities. In this regard, we investigate seven predominant sectors including the environment, public transport, utilities, street lighting, waste management, public safety, and smart parking that have a great effect on SC development. Our findings show that for the environment sector, cleaner air and water systems connected to IoT-driven sensors are used to detect the amount of CO₂, sulfur oxides, and nitrogen to monitor air quality and to detect water leakage and pH levels. For public transport, IoT systems help traffic management and prevent train delays, for the utilities sector IoT systems are used for reducing overall bills and related costs as well as electricity consumption management. For the street-lighting sector, IoT systems are used for better control of streetlamps and saving energy associated with urban street lighting. For waste management, IoT systems for waste collection and gathering of data regarding the level of waste in the container are effective. In addition, for public safety these systems are important in order to prevent vehicle theft and smartphone loss and to enhance public safety. Finally, IoT systems are effective in reducing congestion in cities and helping drivers to find vacant parking spots using intelligent smart parking.

Keywords: smart cities; Internet of Things (IoT); strategy; monitoring

1. Introduction

While old, crowded cities are under pressure from many issues such as population explosion and improper infrastructure, the rise of smart cities (SCs) has provided a good solution for solving many of the existing problems and overcoming urban challenges [1]. Therefore, the rapid development of SCs in recent years reflects their importance [2]. In fact, SCs with greater opportunities for citizens and proper services are becoming an

attractive choice for people and communities, and they can be a place for fostering success in health and businesses across the world with the help of smart infrastructure [3]. On the other hand, achieving SC development requires detailed and specific planning and the proper implementation and establishment of policies. Thus, identifying obstacles can grant us a deeper understanding of how to determine the best solutions with less difficulty [4]. Since, in developing SCs, we are faced with numerous barriers and problems in various areas, such as roadways, environment, utilities, parking, public safety, waste management, and public transport, it is pertinent to enhance these sectors through accurate investigation and practical actions [5]. To overcome such barriers, SC governments must implement appropriate strategies and present proper solutions to mitigate or eliminate these barriers [6]. In this regard, the role of the Internet of Things (IoT) and the utilization of these systems is an essential and beneficial strategy to appropriately develop SCs [7]. In fact, with the appearance of new technologies such as the IoT, the concept of SCs has changed and continues to evolve for the better, subsequently improving and accelerating urban management across various sectors [8]. This means that the utilization of the IoT leads to the development of smart cities [9]. In recent years, many types of research have been conducted on SC development [10]. For instance, the importance of the IoT for SC development was also reviewed by Badis Hammi et al., who demonstrated that a higher level of interaction between SCs and IoT development is essential, as it can integrate electronic devices. However, the safety risks and privacy issues of participating individuals, companies, and organizations should be considered carefully in such cases [11]. Ejaz et al., investigated efficient energy management for the IoT in the context of SCs and observed that such management is a key paradigm to monitoring complex energy systems. They also showed that efficient energy management can support wireless energy transfer for IoT devices and energy-efficient planning in smart homes [12]. Tanveer et al. investigated the growth of the IoT markets across energy systems of SCs. Regarding the importance of smart grid technology innovations in supporting smart energy systems in SCs, the study showed that investment in these systems has increased in recent years. Based on the literature, the IoT of the global energy market exceeded USD 6.8 billion in 2015 and is anticipated to reach USD 26.5 billion by 2023, which portrays an annual growth rate of 15.5% between 2016 and 2023 [13]. Bresciani et al., investigated the IoT in terms of organizations, in order to innovate and implement it in everyday business activities. The results from the 43 IoT SC project alliances across Italian cities they investigated demonstrated that multinational enterprises are building alliances for exploring new technologies for cities as well as exploiting new IoT-based devices to gain economic profit. The study proved that for companies to achieve the desired results, they must integrate different types of knowledge to ensure efficient management and effective support [14]. Evertzen et al., analyzed the effects of smart governance on the quality of life in SCs in the three well-known cities of Palo Alto, Nice, and Stockholm. This research emphasized the importance of innovative approaches across SCs, which should be implemented based on the IoT, and consequently, many services should be promptly digitalized. Therefore, in order to achieve these goals and successfully implement an SC model, strong leadership, citizen involvement, and business collaboration are required [15]. With regard to the importance of transportation systems in SCs, the prospect of handling considerable information using sensor data from the environment for better monitoring of transport systems in SCs was examined by AlZubi et al., as the time data extracted from sensors is important; the researchers presented a responder-dependent add-on information fusion scheme concerning sensor data. This guided vehicle scheme can observe the responding sensor information in order to determine the success of the goal endorsed. This scheme, which is based on classification machine learning, can help us identify and subsequently reduce the errors caused by sensor information [16]. In light of the importance of the IoT in the development of smart cities, this article examines the problems and solutions of seven key sectors that have a significant impact on SC development, including the environment, public transportation, utilities, street lighting, waste management, public safety, and smart parking. We also considered certain important

cities in the EU (Paris, London, Copenhagen, Barcelona, Amsterdam, and Oslo) and in the United States (Boston, New York, and San Francisco) based on the relevance of the IoT.

2. Motivation and Objective of the Critical Review

Creating and developing SCs is an important objective for many countries [17] to enhance the life quality of their population through the optimal management of their resources [18]. In addition, SC development supports global mitigation strategies, especially across the environmental and energy sectors [19]. One of the most important factors for SC development is the IoT [20], which integrates different systems related to energy, transport, and waste and water management within SCs in order to enhance the inhabitants' quality of life [21]. Given that more of the global population resides in urban areas, therefore it can be said that cities are held accountable for the majority of the global energy consumption and greenhouse gas (GHG) emissions [22]. Thus, a reduction in energy use and the maximization of renewable energy use, when available, can support these objectives. The use of the IoT in SCs provides an opportunity to make incremental changes in efficiency by harnessing new technologies and automating processes in applications [23]. It is important to recognize that the innovation, advancement, and implementation of the IoT across SCs have a dynamic impact on many other intertwined systems, including the environment, economy, and transportation. Therefore, it is crucial to create an in-depth understanding of these independencies to ensure that negative impacts are not overlooked and positive impacts are enhanced and used to create an incentive to create changes across cities. The aims of this study include investigating the concept of SCs, identifying the IoT barriers across seven important sectors, and compiling appropriate solutions to tackle each barrier.

3. Methodology

To identify the potential barriers to IoT development in SC development and, based on the importance of the IoT, we conducted an exhaustive review of more than 400 relevant publications related to the IoT, and have searched in Internet the using established scientific databases, such as Google Scholar, Scopus, Web of Science and Journal sites (Taylor & Francis, Elsevier, MDPI, Springer, Willey, etc.).

In this regard, we searched, in the Internet, words such as smart cities, environment, road traffic, public transport, utilities, smart lighting, public safety, waste management, street lighting, and smart parking. In the first step, between 2019 and 2020, we investigated more than 200 review papers to understand the concepts of the IoT and smart cities. Then, we investigated, in 2021, more than 200 technical papers, and eventually selected 121 papers. After these steps, we categorized the most important papers which helped us to start writing this paper and we selected the methodology. Review articles helped us understand SC development and the IoT technologies that have come under the spotlight within a short period of time. Moreover, technical articles established a deeper understanding of effective policies in SC development relative to the IoT in order to obtain proper solutions to the barriers. Figure 1 shows the flowchart for the methodology of this study. After all the relative papers were collected, the articles were categorized into two groups—review papers and technical papers. We based the methodology on the best of these. In the last step, we determined recommended actions and policies to achieve the goal of the paper.

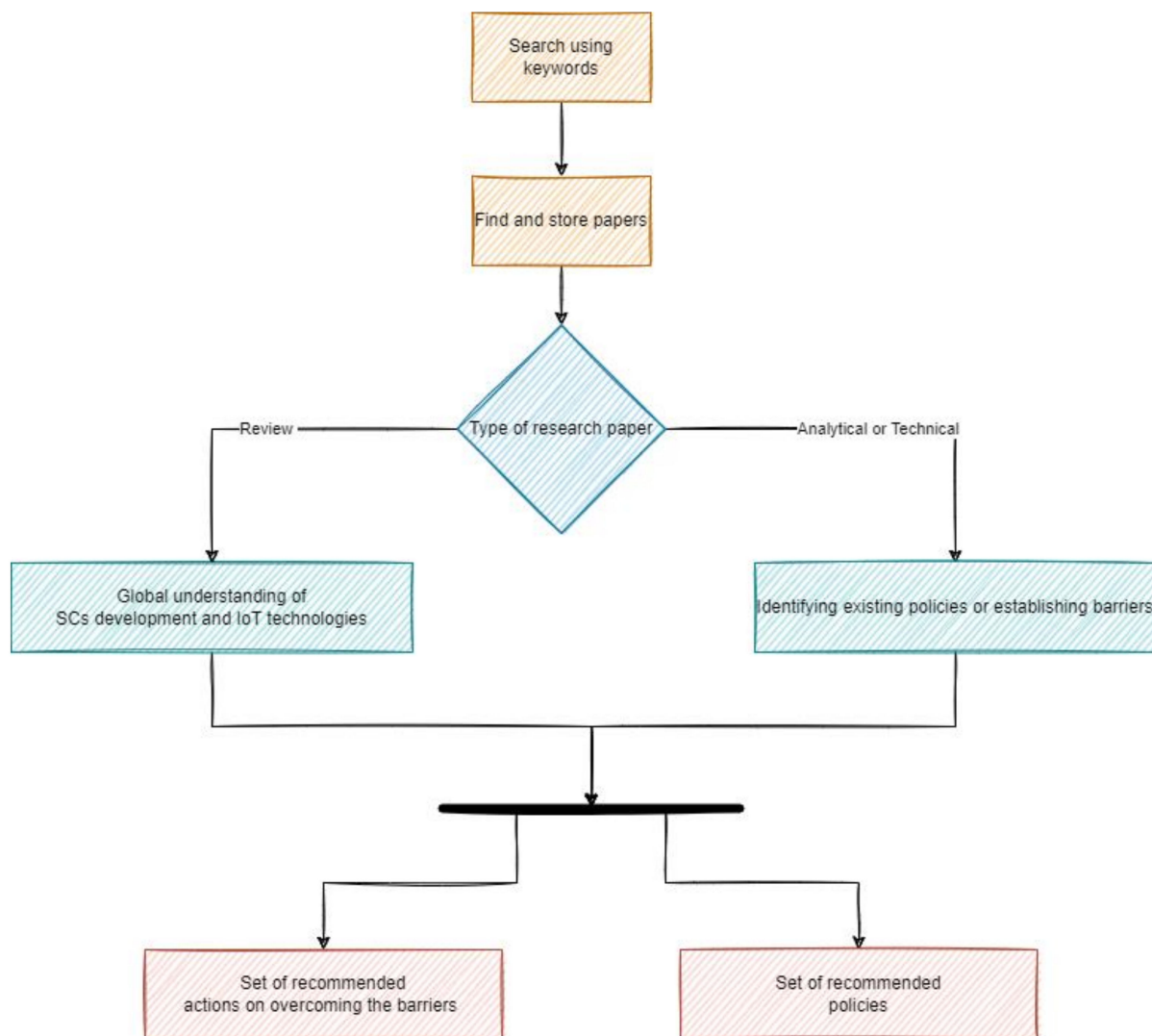


Figure 1. The methodology flowchart.

4. Results and Discussion

4.1. Recognizing the Existing Obstacles in the Development of SCs

As we are faced with various barriers and problems across seven specific sectors in SCs, i.e., environment, public transport, utilities, street lighting, waste management, public safety, and parking, we believe that the utilization and implementation of the IoT will be effective in mitigating or resolving the problems associated with these areas. In the following sections, we comprehensively discuss these problems and the solutions that we obtained from the review articles and scientific research.

4.1.1. Environment

Cleaner air and water systems are crucial elements of the environment [24]; for this, a network of sensors should be used to monitor air [25] and water quality [26]. Specifically, sensors can be used to detect the amount of CO₂, sulfur oxides, and nitrogen to monitor air quality and to detect water leakage, pH levels, and changes in the chemical composition of water. Therefore, sensors can be implanted along busy roads, around plants, and near houses, offices, and organizations [27]. Moreover, it is necessary to utilize sensors for detection and monitoring and to obtain data and results [28]. According to the McKinsey Global Institute, emissions can be reduced by 10–15% through applications that focus on building automation, mobility, and dynamic electricity pricing. Thus, SCs can support and

contribute to a cleaner and more sustainable environment [29]. Nowadays, sensors, as well as environmental sensors, have significantly affected lives, as individual environmental sensors obtain data about the environment and then transform that data into electrical signals to feed higher-level systems around the individual sensors. The advantages of these sensors are lower cost, smaller size, and reliability [30].

4.1.2. Public Transport

Considering the safety and efficiency of citizens of SCs is crucial, especially on roads [31]. Therefore, municipalities are attempting to implement smart traffic using IoT development solutions [32]. In this regard, the IoT will play a crucial role in traffic management. For instance, data from various types of sensors and GPS systems are sent by drivers' smartphones in order to determine the speed, number, and locations of vehicles on a particular road. Subsequently, smart traffic lights are immediately connected to a cloud-management platform and provide timing information to automatically and accurately monitor green lights, thereby preventing traffic congestion. Additionally, these methods can predict traffic in the future and offer prevention plans, with which the transport administration department is able to detect potentially dangerous situations in time and take required actions to prevent traffic congestion [33]. Therefore, considering the obvious importance of transportation systems in SCs, specific and accurate planning to control these systems is necessary [34]. According to [35], transport technological development with the IoT will have a big revolution between 2020 and 2030, that will have direct impact on toll operators and highways and provide safe and secure networks [35]. In addition, traffic data from multiple sources, such as traffic information and ticket sales, can be used to perform sophisticated analyses and achieve better results, and train operators can maximize the capacity of tracks and easily prevent train delays [36]. Fortunately, many countries around the world, especially developing countries, are now trying to make use of new systems connected to the IoT for controlling their transportation systems [37].

4.1.3. Utilities

IoT-equipped SCs give more control to citizens over their home utilities, reducing overall bills and related costs [38]. By utilizing IoT technologies and effective approaches, such as smart meters for billing, monitoring consumption patterns, and remote monitoring, municipalities can achieve cost-effective connectivity to utility companies' IT systems. This helps customers consume energy and water based on improved monitoring and, therefore, presents better management services to the citizens [39]. Precooling optimization using system data (IoT), while preserving the thermal comfort of the inhabitants, has a direct influence on expenses and energy consumption (electricity costs) for cooling of a building by up to 30% percent, according to an Australian study [40]. Also, other research shows that, in Arabian Gulf countries, a smart energy management system using the Internet of Things can reduce costs, especially for air conditioning, which accounts for up to 60% of electricity consumption, while still meeting energy demand [41]. On the other hand, use of the IoT in utilities has a good effect on attainment of efficiency (management of large-scale solar photovoltaic systems) [42] and conservation of resources [43].

4.1.4. Street Lighting

In SCs, the maintenance and control of streetlamps can be more cost-effective and straightforward through the use of the IoT [44]. In particular, IoT systems can be paired with sensors that connect to a cloud-management solution [45], providing confident monitoring of illuminated transport paths such as streets and the movement of people and vehicles. Measuring the environmental conditions can also allow for a more accurate analysis regarding the need to improve the lighting schedule and indicate if lights should be brighter or dimmer [46]. On the other hand, IoT systems have a remarkable effect on energy-saving associated with urban street lighting as using warmer lights and increasing light uniformity can result in a 30–50% energy saving on street lighting, and for medium-sized cities with

populations around 200,000–400,000 residents, energy savings on street lighting it can reach 8–23 MWh per annum [47].

4.1.5. Waste Management

Waste collection is one of the most important sectors of SCs [48]. In this regard, IoT can reduce a lot of problems in this regard [49]. To achieve this, a sensor will be placed on each waste container, which will gather data regarding the level of waste in the container; then, after the container is filled, a notification will be sent to truck drivers via a mobile app. By following this useful and effective plan, truck drivers will expend time and energy to only empty full containers instead of half-full ones [50]. A study in China of recycling and household waste segregation between 2018 and 2019 showed that integration of the Internet of Things (IoT) was effective in household waste management. During the study, collections of recyclable waste and biodegradable food waste were elevated by 431.8% and 88.8%, respectively, which had good environment effects and meant that this macro policy increased the recyclable waste collection by 431.8% in Shanghai [51].

4.1.6. Public Safety

Theft of motor vehicles throughout the world, coupled with a massive loss of cash, is a disaster for insurance companies. For instance, just in the USA, in 2019 about USD 6.4 billion was lost to motor vehicle theft [52]. Likewise, every year, worldwide, 70 million smartphones are lost or stolen [53]. In these regards, IoT-based SC technologies are vital for offering real-time monitoring, enhancing public safety, and supporting proper decision-making, that will prevent a lot of harm to people [54]. For example, testing of the motorcycle antitheft system (MATS) showed that this system had 100% accuracy at speeds of up to 70 km/h and for speeds up to 80, it had 94.4% accurate [55].

4.1.7. Smart Parking

Parking occupies a large amount of the area in a city—81% of the city area in Los Angeles, 23% in Munich, 23% in Paris, 19% in Copenhagen, and 18% in Zurich and Hamburg. Therefore, cities must use of intelligent parking systems in order to reduce congestion and help drivers [56]. In this regard, IoT technology has built a special mobile application in order to solve vehicle parking problems and this has had a remarkable effect for drivers. Based on research, from 2013 to 2018, downloading of the mobile application, increased from 17 million downloads to 80 million, which shows the benefit of this application in solving problems related to parking [57]. Therefore, the importance of smart parking in SCs should be investigated by policymakers [58], considering that finding parking spots can improve the welfare of citizens [59]. This action can be achieved by utilizing GPS data from drivers' smartphones and road-surface sensors embedded in the ground of parking spots. As a result, drivers can be notified of occupied and vacant parking spots via a real-time parking map [60].

4.2. *Strategic Policies for Boosting Economic Recovery of Smart Cities through the IoT*

The IoT technology inherent in smart cities, promises effective options that will allow cities to be more safe, inclusive, and resilient [61]. In this regard, the IoT helps cities to improve good governance and privacy which are important for the socio-economic dimensions of urban areas [62]. In addition, the advance of 5G technologies [63] and artificial neural networks (ANNs) will prompt further innovations in smart city technologies of the IoT [64]. In fact, cloud-based IoT applications that contain information gathered from citizens could help smart cities to monitor and manage crime detection, proficiency, water supply systems, healthcare facilities, electric utilities, digital libraries, transportation networks, resource management, waste management, and security mechanisms [65]. Therefore, smart technologies such as the IoT are significant when developing SCs, while maintaining emphasis on the implemented strategies and policies [66]. It is clear that the implementation of targets related to SCs requires strong and calculated strategies and

policies [67]. In fact, achieving “smartness” is not a one-time action; it is a continuous process. Therefore, policymakers should aim to devise a plan [68] that considers the individual goals of each sector whilst also evaluating the dynamic and indirect impacts on other areas within an SC. Undoubtedly, to advance SCs and continue their expansion, officials and policymakers must vigorously strive to create a unique quality of life, work, and environment for the citizens of their cities [69]. On the other hand, since the concept of SCs falls in line with the smart grid, economic issues related to the programs that are used for demand-response management (DRM) and real-time pricing should be taken into consideration [70]. In addition, it can be added that as SCs aim to improve the quality of life of urban citizens, the success of SCs depends on participation by private companies [71]. Therefore, through the use of new communication channels between the government and its citizens, policymakers should focus on the essential needs of stakeholders, such as affordable energy, urban security, and energy security [69], because, public participation will help improve quality of life and establish trust between local governments and people [72]. This means that the investment in developing SCs has advantages for both people and the community, including a reduction in the cost of living, improvement of living standards and environmental sustainability, improvement of operational efficiency, improvement of eco-friendly infrastructure, and development of smart technology through the IoT [73]. Moreover, private investment (companies) can help governments easily overcome old issues pertaining to big cities or developing cities that have not been well planned [74]. In general, investment on IoT technologies, is opening new possibilities for cities and helping them to be smart cities [75]. According to these cases, effective strategies and policies can accelerate the conversion of a standard city into an SC and, thus, should aim to attract investment, improve IT infrastructure, integrate connected local energy storage systems in order to support better renewable energy sources on the power grids, and adapt an IoT implementation strategy based on the city’s size to reduce costs, support the utilization of smart LED streetlights in major metropolises, increase the collaboration between local governments and stakeholders, increase the utilization of new technologies such as sensors, change the mentality of the citizens, and redefine the governance model with proper politics. Based on the comprehensive explanations presented above, the most important barriers and the most appropriate solutions related to IoT-based SC development are presented in Table 1.

Table 1. The most important barriers related to SC development based on the IoT and the appropriate solutions.

Sectors	Barriers	Solution	References
Public transport	More CO ₂ emissions due to increased private cars, increase in noise from private cars in cities, lack of monitoring patterns of transport use by citizens, absence or low use of monitoring systems, lack of safety and efficiency in roads, congestion and traffic, sudden accidents, and defective roads	Utilization of proper patterns and use of monitoring sensors, utilization of different types of sensors to accurately monitor roads and improve GPS systems using data from drivers’ smartphones, and improvement in the quality of roads	[29,31,34,36,76–80]
Street lighting	Lack of sensor-equipped street lights and defective lights	Streetlights with sensors and establishment of a connection between the sensors and cloud management, utilization of a monitoring-system switch to scan conditions and send signals to increase or dim the lights, and use of new lights (low consumption)	[43–46,81–84]
Utilities	Excessive consumption, extra expenses for fuel and electricity for which there is no need, lack of or improper use of smart meters and smart billing, shortage of revealing consumption patterns, and limited remote monitoring for citizens	T-equipped smart-connected meters, proper consumption patterns, and management services to improve the quality of the services	[46,85–87]

Table 1. Cont.

Sectors	Barriers	Solution	References
Smart parking	Lack of or limited smart parking options for drivers, improper parking of cars on the street, and reduction in street width due to traffic	Utilization of GPS data from drivers' smartphones or road-surface sensors embedded in the ground on parking spots	[58–60,88,89]
Waste management	Release of garbage and the resultant unpleasant odor in cities due to absence of accurate systems to monitor the proper time to collect waste in order to prevent fuel losses and empty containers	Installation of a sensor on waste containers to optimize waste-collection schedules by tracking waste levels	[90,91]
Environment	Increased CO ₂ emissions and threats public health and lack of water and air quality monitoring	Utilization of different types of sensors such as water sensors and air sensors to improve and provide more accurate monitoring	[24–28,92–94]
Public safety	Weak security of public safety in cities, increase in crimes such as robbery, lack of ethics regarding law and regulatory rights, and weak infrastructure	Utilization of IoT technologies such as CCTV cameras and acoustic sensors in different areas of cities, blockchain-based security management of IoT infrastructure for maintaining security and privacy, improvement of interoperability, leading to vendor lock-in, and control of corruption	[95–103]

To complete this Table, other investigations can be added. For example one of the greatest challenges at present is the low or inadequate quality of the life in many areas of the world. This means that in many areas, use of energy is not based on world standards and there is less use of modern technologies to manage it. This affects the quality of life of citizens, and, in particular, the economy of households [104,105]. Without a doubt, collection of the wastes in crowded areas especially cities, is important for citizens, because it prevents illness. Utilization of IoT is very important in providing more efficient waste management and overcoming other problems in this area [106]. Healthcare is one of the most important challenges for governments because low health of the citizens can have negative effects on people. In this regard, IoT systems can improve net health and increase people's health knowledge [107]. In addition, using e-health services, for instance in a global pandemic such as COVID-19, for data collection by citizens, for giving health advice through the Internet, and for increasing the health of medical staff is fruitful [108]. On the other hand, as mentioned previously, transportation systems are one of most important sectors in many countries because transport has a large effect on the environment and the movement of people. Therefore, today, the emergence of IoT systems inside cars and the conversion to smart cars (vehicles), helps the environment and can also move people easily without loss of time [109,110]. In addition, in order to reduce traffic and help the environment, greater utilization of bicycles and an increase in bike-sharing services has been implemented through IoT systems [111]. Moreover, to improve the electrical energy saving of the cars, increasing the lifetime of battery-operated devices (by up to a couple of years) by using of IoT systems is possible because IoT systems are able, during inactive periods, to keep the device in a low-power state [112]. The issue of the elderly and their care is also important in many countries. Fortunately, however, IoT systems have provided assistance applications through the use of a single wearable device in both outdoor and indoor locations. These systems are able to recognize changes in the behavior of elderly people, are low-cost, unobtrusive, have a low power consumption, and can easily prevent problems [113].

Table 2 shows a comparison between results of this work and a number of works in the literature. As can be seen, most previous work has investigated limited subjects related to the IoT and smart cities, while this work comprehensively investigated these subjects.

Table 2. A comparison of the results of this work and those of previous work.

Present Work	Types of Consideration in Other Work	Reference
Environment	Reviews of IoT-based environment monitoring systems	[114]
Public transport	Managing the public transport systems through applying digital technologies	[115]
Utilities	Investigation of the role of digitalization for smart water networks and improvement by the IoT, artificial intelligence, blockchain, and other novel technologies	[116]
Street lighting	Investigation of the street lighting framework using IoT systems to reduce cost and energy consumption	[117]
Waste management	Proposal of a proof-of-concept municipal waste management system to reduce the cost of waste classification, monitoring, and collection using the IoT	[118]
Public safety	Increase in public safety against theft using IoT systems	[119]
Smart parking	Investigation the role the Internet of Things (IoT) in overcoming the challenges of parking cars. Presentation of smart parking solutions	[120]

5. Conclusions

Future with less CO₂ [121], and relying upon renewable energy [122] as main fuels, are some of the most important goals of scientists and researchers. In this regard, the role of IoT in controlling CO₂ emissions and managing energy consumption is important. This work investigated the problems related to seven important sectors of the IoT, namely environment, public transport, utilities, smart parking, public safety, waste management, and smart lighting. Each sector was analyzed carefully to identify the challenges to be mitigated or removed such that building SCs would be possible. For instance, in the environment sector, the utilization of air and water sensors allows us to monitor air and water quality and detect the amount of CO₂, sulfur oxides, and nitrogen, water leakage, and changes in the pH level and chemical composition of water over time, as well as other factors that have potentially detrimental effects. In terms of road traffic, the determination of the speed, number, and locations of vehicles and monitoring of green-light timings can be achieved through the use of various types of sensors and GPS data collected from drivers' smartphones. Across the public-transport sector, IoT sensors can help enhance our travel experiences and achieve a higher level of safety and punctuality. In utility monitoring, the IoT allows users to control their home utilities for billing, consumption patterns, and remote monitoring. In particular, via cost-effective connectivity to utility companies' IT systems, customers can adjust their energy and water consumption more economically. For street lighting, utilizing both IoT systems and sensors connected to a cloud-management solution can ensure the confident monitoring of illuminance for the safe movement of people and vehicles. In terms of environmental effects, we can improve the lighting schedule and determine which areas require different intensities of light (some streets may only need a dim light, so less electricity would be used). In the waste-management sector, the use of IoT technologies can lead to the optimization of waste-collection schedules by tracking the waste levels, providing route optimization, and ensuring useful operational analytics. In this regard, each waste container would be implanted with a sensor that gathers data on the level of waste in a container. Then, a notification of filled containers would be sent to truck drivers via a mobile app. This is a strategic plan to avoid emptying half-full containers, resulting in less travel by trucks and reducing GHG emissions. In the public-safety sector, IoT-based SC technologies have a crucial role in offering real-time monitoring, enhancing public safety, and developing decision-making tools and analytics through CCTV cameras and acoustic sensors. At the same time, data from social media feeds can be carefully analyzed to improve public safety in a city and predict potential crime scenes. For the smart-parking sectors, IoT technologies can help drivers identify available parking spots

on a real-time map based on GPS data extracted from drivers' smartphones or road-surface sensors embedded in parking spots.

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