IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 787
Research Paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

Smart Cities in the IoT Era: A Comprehensive Review of Technologies, Applications, and Challenges

Sahil Godara
Deptt. of CSA, BMU Rohtak, Haryana (sahilgodara093@gmail.com)

Dr.Vinod Kumar Srivastava
Professor, Dept of CSA, BMU, Haryana India

Abstract - *New technologies are increasingly being integrated with various components to enhance the functionality of smart cities. These intelligent urban environments heavily rely on IoT (Internet of Things) communications to foster the concept of a "Smart City." This is achieved by leveraging advanced communication technologies to improve services for citizens and city administration. Smart cities have witnessed the installation of numerous IoT-based devices, where the Internet of Things is a modular method to integrate different sensors with all forms of ICT (Information and Communication Technology). This discussion offers an in-depth look at smart cities' concepts, features, and applications. It delves into intelligent cities' usage, challenges, and prospects, seeking insights from current technological advancements and perspectives, including blockchain and machine learning, within cloud and fog IoT ecosystems built on IoT devices, architectures, and machine learning techniques.*

Moreover, the text highlights the importance of privacy and security measures, such as blockchain technologies, in developing smarter, more secure, and resilient urban areas. It also presents a conceptual framework for the mega-events in intelligent cities, underscoring these urban centres' key ideas, features, and applications. Finally, it contemplates the impact, applications, and challenges of emerging technologies in the evolution of modern intelligent cities.
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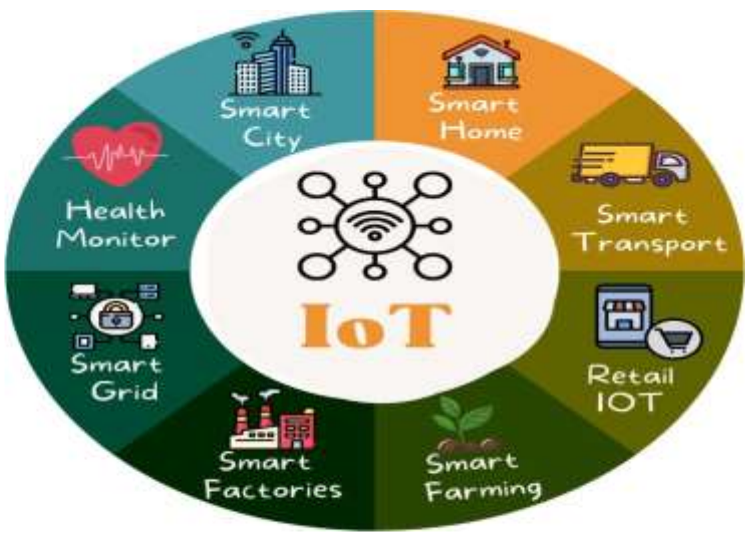
keywords- IoT, Smart Cities, Smart Lighting System, IoT-driven smart cities

1 INTRODUCTION

The "Internet of Things" (IoT) was first used in 1999 after Internet-based technology had been around since the 1990s [1]. The Internet of Things is a group of real-world gadgets that can connect and talk to each other in various social, environmental, medical, and user settings. Things like cars, houses, and even simple electrical tools are all part of the Internet of Things (IoT). These things are linked together to collect and share data [2]. There needs to be a lot of new facilities and services for city dwellers because the population density in urban areas has grown so much. The world's population is expected to grow by more than 10% over the next 30 years, with 70% of that growth happening by 2050. Most of these new people will live in cities [3]. Because of this, countries are thinking about how to get their towns ready for the large number of people coming and the stress that will put on the infrastructure already there. Figure 1 shows the Internet of Things (IoT) uses needed to support this technology. The devices can now connect and talk to each other on the Internet, and digital devices like sensors, motors, and cell phones are being used in many more ways. These "Things" can set priorities, organise themselves, and talk to other "Things" [4] without any help from a person. The Internet of Things aims to make the World Wide Web more widespread and immersive. By using the vast amount and variety of data that "things" make, the Internet of Things will speed up the development of many apps that offer new services to companies, consumers, and government agencies. These smart technologies are used in smart cities for many things, like controlling traffic, saving energy, lowering pollution, and managing traffic. This is the primary goal of smart towns, and it can change how we see the world. We can all say that the Internet of Things will affect every part of life, from everyday tasks to deep feelings. Most of the time, smart city apps and the surroundings around them are best for people who live there [5]. Because of this, dynamic development and complexity make it necessary for megacity planners to use new methods and models. It needs to adapt to new technologies, moving from being technology-driven (SC 1.0) to being driven by city governments, citizens, Industry 4.0 (4G, 5G, electric cars, etc.), and finally to being driven by A.I. and cognitive computing (SC 5.0) [6,7].

In Fig. 1, the interconnected landscape of a smart city, the pervasive deployment of Internet of Things (IoT) technologies transforms various sectors, enhancing efficiency, sustainability, and overall quality of life. In smart homes, health monitoring systems leverage IoT to provide real-time health insights, enabling remote patient monitoring and proactive healthcare. Integrating smart grids optimises energy distribution, minimising wastage and promoting sustainability. IoT facilitates intelligent traffic management, predictive maintenance, and efficient route planning in smart transportation, reducing congestion and lowering emissions. Retail IoT transforms the shopping experience through smart inventory management, personalised customer interactions, and efficient supply chain operations. In agriculture, smart farming utilises IoT sensors and data analytics for precision farming, optimising resource usage and improving crop yields. Meanwhile, IoT-enabled automation, predictive maintenance, and real-time monitoring in smart factories revolutionise manufacturing processes, enhancing productivity and minimising downtime. The collective integration of IoT across these diverse domains exemplifies the comprehensive impact of innovative city initiatives, fostering innovation and sustainability on a global scale.

Figure 1: Applications of IoT for supporting smart cities.[4]



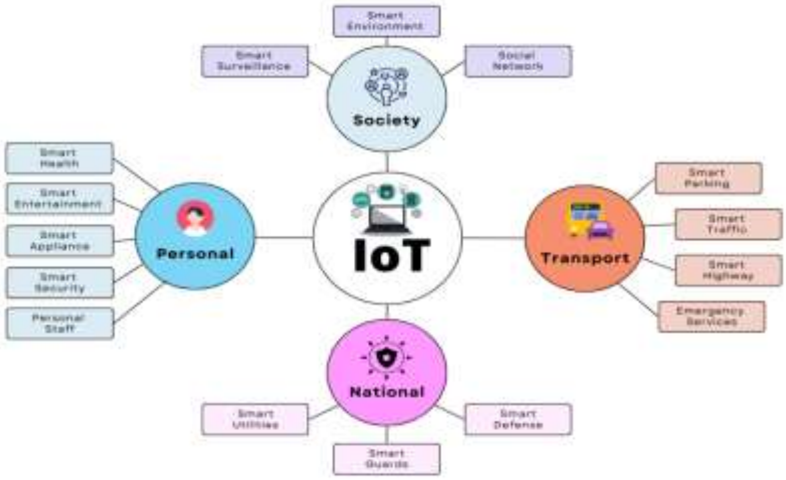
The idea of a "smart city" has grown for good reason. First, cities are growing faster than ever because that is where most of the new jobs are. Second, many families from rural areas are moving to cities to give their kids better schooling chances [8]. This habit has caused several significant issues. To keep up with this population increase, cities must add more services and infrastructure. Also, answers should be found for several problems, such as those related to the environment and transportation in cities. The idea of a "smart city" was created to solve these issues. A smart city's basic infrastructure needs and uses many devices, support tools, and everyday things that happen in cities. People think the Internet of Things is one of the most essential parts of making an innovative city work [9]. Internet of Things (IoT) applications to make sure that the essential parts of intelligent cities work correctly, like fire alarms, water and power supplies, and speciality processing, as well as other production capabilities [10]. Figure 2 displays how important IoT parts for smart towns are linked together. Figure 2 is an overview of smart cities' concepts, features, and uses; the Internet of Things (IoT) has various applications across various domains, impacting personal and societal aspects. Here is a breakdown of how IoT is utilised in different areas:

Internet of Things (IoT) technology has permeated various aspects of our lives, enhancing personal experiences and contributing to developing intelligent solutions across different domains. On a personal level, individuals are increasingly incorporating IoT into their daily lives. In wise health, wearable devices and health monitoring systems utilise IoT to track vital signs, provide real-time health insights, and facilitate remote patient monitoring, thus promoting a proactive approach to healthcare.

In smart entertainment, IoT devices enable personalised content delivery and immersive experiences. Intelligent home appliances leverage IoT to enhance efficiency and convenience, allowing users to control and monitor devices remotely. Similarly, intelligent security systems employ IoT for real-time monitoring, smart surveillance, and instant alerts, bolstering the safety of individuals and their assets.

IoT applications extend beyond personal spaces to impact society at large. In the context of smart surveillance, IoT-enabled cameras and sensors enhance public safety by providing real-time monitoring of public spaces. Smart environmental solutions utilise IoT to monitor and manage environmental parameters, contributing to sustainability efforts. Social networks are also influenced by IoT, facilitating seamless connectivity and communication between individuals and communities. In transportation, IoT plays a pivotal role in developing smart parking solutions, optimising parking spaces and reducing traffic congestion. Smart traffic management systems utilise IoT to monitor and regulate traffic flow, enhancing overall roadway efficiency. The concept of smart highways integrates IoT for real-time communication between vehicles and infrastructure, promoting safer and more efficient transportation. Emergency services benefit significantly from IoT applications. The integration of IoT in emergency response systems enables quicker and more targeted responses to crises, ensuring the timely deployment of resources and assistance. IoT is employed in smart utilities at the national level, contributing to efficient resource management and sustainable practices. Smart guard and defence systems utilise IoT for enhanced surveillance, border control, and national security measures.

Figure 2: Interconnection of IoT components in smart city scenarios [4]



1.1 Smart Lighting System (SLS):

Integrating Internet of Things (IoT) technology with LED lighting systems has paved the way for developing smart cities. This innovative approach combines energy-efficient lighting solutions with interconnected sensors and communication networks to create intelligent urban environments. In smart cities, IoT-enabled LED lighting systems offer a range of benefits and functionalities. These systems can have sensors to monitor and adjust lighting based on ambient light levels, pedestrian or vehicular traffic, and weather conditions. Additionally, incorporating IoT technology allows for centralised control and monitoring of street lights, enabling more efficient maintenance and energy management.

Furthermore, smart LED lighting systems can be a backbone for various smart city applications, including environmental monitoring, smart parking, and enhanced public safety. The synergy between IoT and LED lighting contributes to sustainable and resource-efficient urban development, making cities more livable and responsive to the needs of their residents.

Table 1 shows the Summary of specifications of the IoT-enabled communication protocols used in a Smart Lighting System (SLS)[5]. Various wireless communication protocols, each tailored to specific requirements, play a crucial role in facilitating the connectivity of IoT devices. Based on the IEEE 802.11 standard, Wi-Fi provides high data rates of up to 3 Gbps with a range of typically 100 meters. Operating in the 2.4 GHz or 5 GHz frequency bands, Wi-Fi supports various topologies such as star, mesh, and access point configurations. Security measures include WPA2/WPA3, EAP, and TLS protocols, ensuring robust protection against unauthorised access. Zigbee, compliant with IEEE 802.15.4, offers lower data rates, reaching up to 250 kbps, with a typical range of 10-100 meters. Zigbee supports mesh and star topologies operating in the 2.4 GHz frequency band. Security is enforced through AES-128 encryption and link-layer protection mechanisms.

Bluetooth, particularly Bluetooth Low Energy (BLE), achieves data rates of up to 2 Mbps over 10-100 meters in the 2.4 GHz frequency band. Common topologies include star and piconet configurations, with security features like AES-128 encryption and ECDH for secure key exchange.

ISSN PRINT 2319 1775 Online 2320 787
Research Paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

LoRaWAN (Long Range Wide Area Network) utilises LoRa technology, offering lower data rates, up to 50 kbps, over several kilometres. Operating in various frequency bands, LoRaWAN supports star and mesh topologies, employing AES-128 encryption and HMAC for securing communications. NB-IoT (Narrowband IoT), operating in licensed cellular bands, achieves data rates of up to 250 kbps over several kilometres. Supporting star and cellular topologies, NB-IoT leverages LTE technology and incorporates SIM-based security measures to ensure network integrity. MQTT (Message Queuing Telemetry Transport) and CoAP (Constrained Application Protocol) are popular protocols for Internet-scale communication. MQTT operates over TCP/IP, providing variable data rates and supporting a publish/subscribe topology. Security measures include TLS and username/password authentication. On the other hand, CoAP operates over UDP/DTLS with a request/response topology, implementing DTLS and OAuth for secure communication.

Table 1: Summary of specifications of the used in a Smart Lighting System (SLS)[5]

Protocol	Wireless Technology	Data Rate	Range	Frequency	Topology	Security
Wi-Fi	IEEE 802.11	Up to 3 Gbps	Typically 100m	2.4 GHz or 5 GHz	Star, Mesh, AP	WPA2/WPA3, EAP, TLS
Zigbee	IEEE 802.15.4	Upto 250 kbps	Typically 10-100m	2.4 GHz	Mesh, Star	AES-128, Link-layer
Bluetooth	Bluetooth Low Energy (BLE)	Upto 2 Mbps	Typically 10-100m	2.4 GHz	Star, Piconet	AES-128, ECDH
LoRaWAN	LoRa (Long Range)	Upto 50 kbps	Several kilometres	Various bands	Star, Mesh	AES-128, HMAC
NB-IoT (Narrowband IoT)	Cellular	Upto 250 kbps	Several kilometres	Licensed bands	Star, Cell	LTE, security, SIM
MQTT	Internet Protocol	Variable	Internet Scale	TCP/IP	Publish/Subscribe	TLS, username/password
CoAP	Internet Protocol	Variable	Internet Scale	UDP/DTLS	Request/Response	DTLS, OAut

2 RESEARCH METHODOLOGY

Different approaches have been suggested in the published work for smart city frameworks and solutions in various application areas. This research work will be initiated by considering the earlier works done in the past. Categorically, the reviews of previous work would be carried out as discussed below:

2.1 Data Collection:

Data Sources:

Academic Journals:

- Explore peer-reviewed journals from reputable sources such as IEEE Xplore, Springer Link, and other relevant databases.
- Look for articles discussing sustainability, smart cities, IoT, and LED lighting systems.

Conference Proceedings:

- Access conference proceedings from events focusing on IoT, sustainability, and smart city technologies.
- Identify key conferences in the field and search for relevant papers.

Online Repositories:

- Utilise reputable online repositories, particularly those specialising in educational research.
- Access databases that host relevant materials related to sustainability, IoT, and smart city technologies.

2.2 Search Process:

Keywords:

Primary Keywords: Sustainability, Smart Cities, IoT, LED Lighting System.

Secondary Keywords: Energy Efficiency, Urban Development, Internet of Things, Sustainable Technologies, Connected Lighting.

Boolean Operators:

- Combine keywords with Boolean operators (AND, OR, NOT) for effective search queries.
- Example: "Sustainability AND Smart Cities AND IoT AND LED Lighting System."

2.3 Data Selection:

Inclusion Criteria:

Relevance to the Research Topic:

- Materials directly addressing the integration of IoT with LED lighting systems in the context of smart city sustainability.

Recent Publication Dates:

- Prioritise recent publications to ensure up-to-date information.

Publications from Reputable Journals and Conferences:

- Include articles from respected journals and conferences in the field.

Exclusion Criteria:

Irrelevance:

- Exclude materials that do not directly contribute to the research topic.

Outdated Information:

- Exclude publications with publication dates outside the defined timeframe.
- Unreliable Sources:
- Exclude materials from sources lacking credibility.

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2.4 Data Extraction:

- Begin the data extraction process by collecting relevant information from the selected sources.
- Extract key findings, methodologies, and conclusions from each source.
- Categorise information based on sustainability benefits, technological aspects, and urban impact.
- Organise extracted data for later analysis and synthesis in the research.
- A structured approach to researching sustainability in smart cities involves systematically gathering, filtering, and organising information on IoT integration with LED lighting systems. This process aids in comprehensively exploring the intersection of sustainability, smart cities, and IoT-enabled LED lighting systems.

Figure 3: Paper Selection Methodology

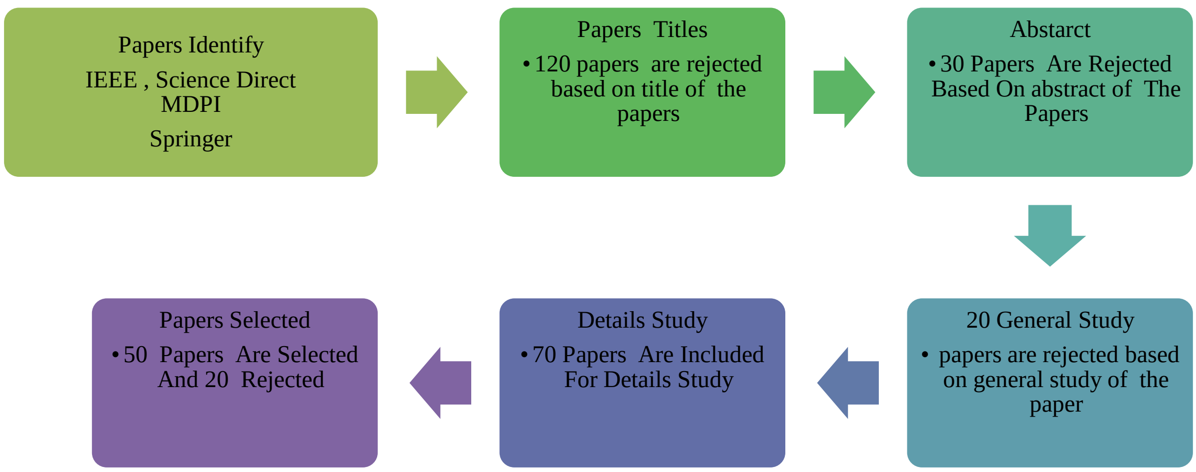

Figure 3 shows the selection methodology for identifying papers for a research study on sustainability in smart cities with IoT-enabled LED lighting systems, which involved screening titles and abstracts from various sources. The initial pool consisted of papers from IEEE, Science Direct, Springer, and MDPI. From the 120 papers initially considered based on their titles, 70 were selected for further investigation. These 70 papers underwent a detailed study, thoroughly examining their content and relevance. Of these, 20 papers were found to be more generalised studies and were subsequently rejected. Additionally, 30 papers were excluded during the abstract screening phase, indicating their abstracts did not align with the research focus. After the detailed study and general study phases, 50 papers were deemed suitable for inclusion in the research.

3 LITERATURE REVIEW

Review of IoT-Enabled Smart City Components and Solutions There is a wide range of research literature regarding the application of IoT in smart city contexts. In the study, [11-12] looked at smart uses such as intelligent transportation systems. The authors discussed smart transportation networks, smart cities, smart houses, smart grids, smart healthcare systems, and more. Other problems that were brought up were privacy and security issues and using blockchain in edge computing. A study on location-based routing protocols for VANETs shows that intelligent transportation systems (ITS) help vehicles work together better to make things more reliable.

A study [13] highlighted important research in fog computing applications that looked at job assignment, task execution, task resumption, and application partitioning. Only one study by Machado and coworkers looked at data forwarding strategies in multi-hop MANETs that used blockchain properties to reward data forwarding.

The author in [14] showed how important the Internet of Things is to building smart towns. Also, the authors showed that smart buildings, transport, healthcare, smart parking, and smart grids are some of the most important ways the Internet of Things can be used in smart cities by looking at 1,802 Scopus papers. Adding the Internet of Things to smart, sustainable urban systems is getting harder because we need to learn how people use these systems to see how well they meet sustainable development goals. This has to be done to reach sustainability goals, such as making people healthier and happier, keeping infrastructure systems running smoothly, saving the environment, and reaching sustainability goals.

The Internet of Things is not a separate technology. Instead, it combines with several other types of smart computers. Cloud computing, fog computing, edge computing, and 5G technologies are some of these concepts[15]. This connection offers powerful, on-demand services that simplify communication, storage, and processing. These services also help with resource allocation, data transfer management, and making IoT operations more easy and effective, which helps build sustainable cities. Earlier, it was said that this kind of integration helps towns become more eco-friendly. Together with focusing on the three most important applications for the goals of sustainable cities [16], each of us thinks combining these technologies is an important addition. The dynamic development and complexity of megacities mean that designers need a new way of thinking about methods and models. Starting with a short history of megacities, we will talk about the current problems these cities have and how smart cities are coming together. A short explanation of the idea of a "smart city" will be followed by a talk about its features and the different generations. In response to technological progress, it has moved from being technology-driven (SC 1.0) to being city government-driven and citizen-driven through Industry 4.0 (4G, 5G, electric cars, etc.) to artificial intelligence and cognitive computing (SC 5.0).

3.1 IoT-enabled smart lighting systems

Cloud computing, fog computing, edge computing, and 5G technologies are some of these concepts. This connection offers powerful, on-demand services that simplify communication, storage, and processing. These services also help with resource allocation, data transfer management, and making IoT operations more easy and effective, which helps build sustainable cities. Earlier, it was said that this kind of integration helps towns become more eco-friendly. Together with focusing on the three most important applications for the goals of sustainable cities [17], each of us thinks combining these technologies is an important addition. The dynamic development and complexity of megacities mean that designers need a new way of thinking about methods and models. Starting with a short history of megacities, we will talk about the current problems these cities have and how smart cities are coming together. A short explanation of the idea of a "smart city" will be followed by a talk about its features and the different generations. In response to technological progress, it has moved from being technology-driven (SC 1.0) to being city government-driven and citizen-driven through Industry 4.0 (4G, 5G, electric cars, etc.) to artificial intelligence and cognitive computing (SC 5.0).

In [18], the author proposed an Intelligent Street Lighting System for a Smart City. This system aims to use streetlights less energy by developing and incorporating cutting-edge technology into the built-in system. The answer to the problem of too much energy use is available in this study. The clever street lighting system comprises radio frequency (R.F.) controllers, LED lights, ultrasonic sensors, light-dependent resistors (LDRs), solar panels, and networks for short-range communication. When a person uses the LDR sensor and the ultrasonic sensor, a person can find out both how bright the light is and whether there is something under the street pole. Future work will be possible on enhancing distance using more street lights using ultrasonic sensors with Auto-switching energy saving.

Wadim Strielkowski [19] et al. (2020) believe that smart towns should be both energy- and cost-efficient. The goals of this study are to (1) look at the things that make an economy efficient and (2) look at the measures for energy security in smart towns. One of the main methods used in the study is an economic analysis of the infrastructure upgrades that save energy in smart cities by using intelligent light-emitting diode (LED) street lighting systems. Looking ahead to the future, researchers are thinking about how to make smart towns use less energy by installing eco-friendly street lighting systems.

Gianfranco Gagliardi [20] et al. (2020) People have developed ideas for more advanced wireless street lighting solutions. This essay discusses the outcomes of a study and research project called SCALS (Smart Cities Adaptive Lighting System), which was just completed. The project aimed to create all the hardware and software parts of an adaptive urban smart lighting architecture so cities and towns could handle and control streetlights.

Further research can improve the efficiency of smart light systems and decrease energy consumption.

Giuseppe Cacciatore [21] et al. proposed a cost analysis of smart city lighting solutions. New smart lighting solutions will be used in the next wave of smart cities. This article suggests some guidelines and creates a way to compare them. Lampposts that have been connected to the Internet of Things (IoT) are used in the smart lighting ideas that are being shared. When no people are nearby, these lampposts can save energy by turning off or dimming the light. More complex solutions can be looked into. For example, how does a person set up intelligent lighting systems so that lamp posts on each street dim their lights simultaneously based on predictions of how people will move?

Eisley Dizon et al. (2021) [22] have proposed smart streetlights in Smart City: a case study of Sheffield. The author thinks that smart lighting can be used to make people safer and healthier. The building, on the other hand, not only uses much energy but also costs the local government a bundle. Many governments use a steady or traditional method of lighting the streets. Even though this method does not consider things like traffic patterns or light levels in the area, it still leads to much waste. This piece talks about the pros of having streetlights in Sheffield and the different lighting plans that local governments have tried to use to solve the problem. The relationship between power use and total energy use is an area of study that needs more attention.

Kati Brock et al. (2019 [23] show that Philips Lighting thinks smart towns can be built. In order to get into the growing smart city market, this piece talks about four different business models that current companies could use. These models are based on a detailed study that Philips Lighting did over five years. The study looked at four different smart city environments. Write down the four different types of business models and show how they can be useful to an incumbent in different project and ecosystem settings. With the help of lessons learned from Philips Lighting's move from public lighting to smart cities, it shows different business models and gives existing businesses detailed tips on how to put them into action. The Veghar could become an information centre on how to use lighting to improve the poor shopping environment caused by many stores closing down in the future.

Mahesh Bode et al. (2020)[24] smart street light system uses the Internet of Things to achieve two main goals: the first is to cut down on the amount of work needed by the project by reducing the amount of wasted power; the second is to save energy. Conserved energy can be used in many settings, such as homes, businesses, etc. For this, the LDR sensor is used. With this setup, the LDR sensor controls the area's brightness and turns the street light on or off accordingly. The code can be modified to include reasoning that can get reliable weather information about when the sun goes down, and the stars come out, making the system even better. As a result, the whole process can be automated, with the street light turning on at dusk and off at dawn.

Dr A. Senthil Kumar et al. (2020) [25] According to the person who wrote this poll, the Internet of Things (IoT) is being used to make street lighting smarter for this more modern age. Finding an answer to the energy crisis and building more streetlights worldwide are both very important. Along with the study on Smart Street lighting systems, different sensors and parts used in an Internet of Things setting were also examined and explained. Based on the planned timeline, it will be possible to do more studies on how IoT devices can be used in the present.

Francis Jesmar et al. (2020)[26] have proposed an IoT smart lighting system for university classrooms. The study will make an Internet of Things (IoT) controller device that will use a cloud-based system to manage and keep an eye on the lights in classrooms. It is still possible to progress using A.I. and machine learning ideas. In the future, more changes will be made to the automated control of the lights. So, looking into the understanding can also help a person make changes in the future.

Nirmalrani V et al. (2019) [27] This research suggests a very useful and efficient way to light streets using Arduino-based microcontrollers without extra work. The main goal is to create a sharp, urgent streetlight that can be used to show important information in the lighting of important areas, urban areas, and only smart urban areas. This structure has an LED luminaire, an LED driver, a P.V. board, a charge controller, a light sensor, a distance sensor, and an Arduino. In the future, clients and modellers can talk to each other using different distributed platforms. This will open the door to the possibility of working in the future.

Héctor F. Chinchero et al. (2020) [28] This study looks at smart light-emitting diode (LED)

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lighting systems used in smart buildings. The study will look at drivers, communication networks, apps, and applications along with protocols and technology. This piece looks broadly at how LED lighting in smart buildings can be controlled. The research also shows an integrated design that can provide the required services and control methods for an intelligent building energy management system for LED lighting systems in smart buildings. This building design is shown in the study. LED lighting research in smart buildings has recently become very famous. There are big chances to study in this area in materials, integration systems, service delivery, and ways to improve and control processes.

Abbas Shah Syed et al. (2021 [29] have proposed IoT in smart cities. A look at tools, practices, and problems in the broadest sense. The author says that the Internet of Things (IoT) is a way for different tools and gadgets to connect without having to talk to each other. Going forward, this could make places around the world even smarter. The writers of this piece talk in-depth about the Internet of Things and how it works with smart towns. The first part discusses the basic parts of an IoT-based smart city. Then, the tools that make these places possible are talked about. The building blocks, networking technologies, and the A.I. methods used in IoT-based smart cities are all part of these technologies. Smart cities need to learn more about how to keep the Internet of Things (IoT) network safe and private. This is particularly true regarding encryption methods, authentication protocols, data anonymisation techniques, and other ways to stop people from getting into the IoT network without permission.

Jorge Higuera et al. [30] will use several IoT-centric lighting designs in this chapter to show how to create and set up IoT-based smart lighting systems for different uses. The last part of the paper discusses some interoperability standards, web service aspects, and business smart lighting platform issues. Shortly, it will be hard to get around the widespread use of Internet of Things (IoT) devices in areas like health and fitness, sensor technology development, and location services.

Carlos-Andrés González-Amarillo et al. (2020) [31] The steps that were taken to study and create an Internet of Things (IoT) system are summed up in this article. The system's goal is to make it easier to provide a clever lighting service in a school setting. A lot of sensors, tracking systems, and controlled activities are connected by the Internet of Things (IoT). The idea behind them is to make system functions and usage data available in real-time through web services. In the context of the Internet of Things, the "things" that are used are "smart things," meaning they have more functions. Future work is possible on saving electrical energy, economic cost, and performance in terms of stability and reliability.

Marc Füchtenhans et al. (2021) [32] This work does a full literature review to see what we know about smart lighting system technology and how it can be used. Many studies have been written about intelligent lighting systems but have not often been used in production and logistics settings. More work must be done to set up and maintain more complicated tools.

Dankan Gowda et al. (2021) [33] discuss various communication methods that can connect to the Internet of Things and discuss the Smart Lighting System. Also, the author looked at several use cases for an indoor and outdoor smart lighting system connected to the Internet of Things. They then put together a report showing how much energy was used in each case. Smart traffic management might let traffic managers use low-cost self-driving solutions, allowing more study into their possible uses. In SLS settings, weather systems that use environmental sensors, like sensors for rain, temperature, and humidity, may also be used.

Pinak Desai et al. [34] An Arduino microprocessor, a Wi-Fi module, and a PIR sensor are used in this article to describe how to solve the problems of smart lights and security. Smart lighting systems could get better in the future. For example, they could be made to send a text message or email alert if something happens, like the state of light changing or someone walking into the room.

Andrea Zanella et al. (2021)[35], this piece aims to give a full analysis of the technologies, protocols, and architecture that make an urban IoT possible. The presentation will also show and talk about the technological solutions and best-practice suggestions that were picked for the Padova Smart City project. This project, which was a proof-of-concept rollout of an Internet of Things island in Padova, Italy, was done with the help of the city government. Further research on implementing open and standardised protocols will be possible, as they are significantly smaller.

Bhagya Nathali Silva et al. (2018) [36] this paper aims to deliver the essence of smart cities. The paper presents a brief overview of smart cities, followed by the features and characteristics, generic architecture, composition, and real-world implementations of smart cities. Finally, each of us presents some challenges and opportunities identified through an extensive literature survey on smart cities. Further research on the prodigious data processing demands and heterogeneity of connected smart things will be possible. Table 2 shows the Overview of smart city models. In various sectors, implementing Internet of Things (IoT) technologies has led to the development key services, each offering distinct advantages while also encountering core issues.

4 Overview of smart city models:

Table 2 shows that IoT is tested for technologies such as CoAP and MQTT data in the agriculture sector, providing a cost-efficient approach to monitoring and managing agricultural processes. However, a limitation arises regarding support for requests per second, which can impact the real-time responsiveness of the system.

For traffic light systems, key services include monitoring waiting time and vehicle density to improve travel time and road safety. The advantages lie in enhancing overall traffic management efficiency. However, the sector faces challenges, particularly without specified core issues. Smart parking solutions provide real-time information about parking space availability, offering advantages such as time savings and reduced energy consumption. However, these systems may not consider external factors like weather conditions or social events, potentially affecting accuracy.

In smart home automation, the key services involve achieving high speed and multitasking capabilities, leading to low-cost capacity solutions. The sector, however, faces challenges related to monitoring tasks, potentially impacting the system's overall efficiency. Smart building implementations with embedded electronics systems aim to improve the quality of life within these structures. Despite the advantages, challenges arise in effectively managing and monitoring these embedded systems.

Smart waste management services prioritise waste separation, promoting organic and recyclable waste handling. However, limitations exist regarding accessibility to public spaces, constraining the widespread adoption of such systems.

Blockchain technologies are pivotal in smart city solutions, offering reliable and secure services. However, the sector faces concerns related to high energy consumption, which can impact the sustainability of these technologies. Smart lighting services evaluate various protocols and offer advantages such as energy savings. Nevertheless, challenges arise regarding security and high installation costs associated with implementing these systems.

Table 2: Overview of smart city models [4]

Sectors	Key Services	Advantages	Core Issues
Agriculture, Building	Testbed for IoT, CoAP, MQTT data	Cost-efficient	Limited support for requests per second
Traffic Light system	Waiting time, vehicle density	Improve travel time, road safety	-
Smart Parking	Parking space availability	Save time, energy consumption	Does not consider weather or social events
Smart Home Automation	High-speed, multitasking	Low-cost capacity	-
Smart Building	Electronics embedded system	Improve the quality of life	Affects monitoring tasks
Smart Waste Management	Waste separation (organic, recyclable)	-	Limited public spaces
Blockchain and Smart City	Evaluate blockchain technologies	Reliability, secure services	High energy consumption
Smart Lighting	Evaluate various protocols	Save energy	Less security, high installation cost

4.1 Applications for Smart Cities

This list of some application areas should be given the most attention when building a smart economy. Any government that works must use ICT tools to get more people involved. Providing many different technologies and tools for social and human capital will make it smarter. In a smart environment, gasoline fumes should be less harmful or dangerous, and there should be other ways to eliminate trash that does not hurt the environment and save natural resources [37-38].

4.2 Waste Management System

A smart environment is an important part of a smart city. It is usually used to find technological answers to problems with changing the natural environment. Collecting and disposing of trash in cities is a regular job that requires much work and affects many social, economic, environmental, and efficiency factors [39]. The way trash is handled has a big effect on the general population's standard of living. In order to better handle trash, sensors, GPS, and LEDs could be put in the trash can. Regardless of traffic, the sensor will let the

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operator know when to pick up the trash can and the best way to get there. When the trash can is full, an alarm goes off for the operator. Following this, the operator tells the trash worker, who has a smartphone, where the trash can is. The trash worker will then go to the spot, pick up the trash, and put the bin back where it belongs [40].

4.3 Smart Parking System

The Car Parking Information System (CPIS) tells drivers how many open parking spots are in several places. The problem of finding parking spots changes how bad it is at different times of the day. Time series analysis methods were used to check if the data about parking spaces being occupied and for how long were collected in a logical order [41-42].

A smart parking system is crucial in developing a smart city, designed to enhance efficiency, reduce congestion, and provide a seamless experience for motorists. In a smart parking process for a smart city with 15 parking spaces, Integrating IoT and technology-driven solutions plays a pivotal role. As a vehicle approaches the designated parking area, smart sensors strategically placed along the parking spaces detect the vehicle's presence. These sensors relay real-time information about the availability of parking spaces to a centralised system. In this process, "turn left" can be integrated into navigation systems or mobile applications, guiding the driver to the specific section of the parking facility with available spaces.

Upon reaching the allocated section, the smart parking system utilises automated gates or indicators to guide the driver to an available parking spot. Smart switches embedded within the parking space communicate with the system to ensure accurate monitoring of the parking process. Once the vehicle is parked, the smart system updates the availability status, providing real-time data to other drivers searching for parking spaces.

In terms of payment, smart parking systems offer convenient and cashless options. Drivers can use mobile applications or smart cards to initiate the payment process seamlessly. Integrating payment switches ensures a secure and efficient transaction, allowing users to pay for the parking duration without needing physical currency or manual payment procedures.

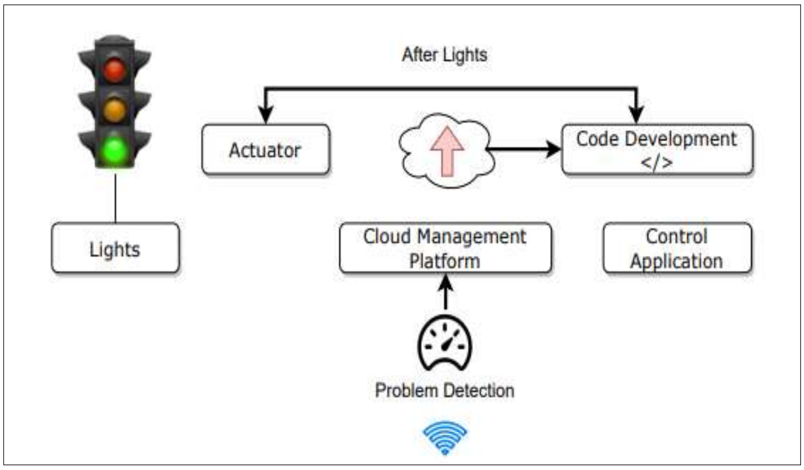
The entire smart parking process, from navigating to the available spaces to payment completion, is designed to streamline the parking experience for drivers while optimising the utilisation of parking spaces in the smart city. Through the integration of advanced technologies and real-time data exchange, smart parking contributes to a smart city's overall efficiency and sustainability goals, reducing traffic congestion and enhancing the quality of urban life.

4.4 Smart Traffic Light System

Smart traffic signals generally improve the air quality in the city. A person can save money on energy costs and lower the risk of accidents caused by too bright lights by controlling the brightness. A very useful Internet of Things app would connect car users and let them know ahead of time about traffic conditions. When the sun goes down and the weather gets bad, cameras with computer vision often look at the road to find oil spills and potholes. There is a chance that sensors along the side of the road could pick up on these signs and decide whether to turn the lights on or off. When a driver exceeds the speed limit, the cloud detection system detects a problem. The officials then take action against the driver who broke the law[43]. Figure 4 shows an advanced device for lighting up the road. In the framework of a smart city, implementing a smart traffic lighting system represents a significant stride toward achieving efficient urban mobility. The smart traffic lighting system integrates multiple components and technologies to optimise traffic flow, enhance safety, and contribute to urban sustainability.

The light actuator is at the system's core, a smart device responsible for controlling traffic signals based on real-time data and algorithms. The actuator utilises sensors and cameras strategically placed at intersections to monitor traffic conditions. These sensors feed data to the control application, allowing the system to dynamically adjust signal timings in response to changing traffic patterns. Developing a sophisticated code is essential to enable seamless communication between the light actuator and the control application. The code incorporates algorithms that analyse incoming data, predict traffic trends, and make instantaneous decisions to regulate signal timings. This code development ensures that the traffic lighting system operates efficiently, reducing congestion and minimising commuter wait times. Cloud management platforms are pivotal in the smart traffic lighting system, providing a centralised data storage, analysis, and system management hub. The cloud platform allows data aggregation from multiple intersections, enabling citywide insights into traffic patterns and performance. It also facilitates remote monitoring and control, empowering city authorities to make informed decisions and adjustments. The control application is the user interface for managing and monitoring the smart traffic lighting system. City officials can access real-time data, view traffic conditions, and adjust signal timings manually if required through the application. This user-friendly interface enhances the system's adaptability to meet the city's specific needs.

Figure 4: Smart traffic lighting system in a smart city.[4]



4.5 Smart Building System

If a person's home has internet-connected and electronically operated devices, this is called home automation based on the Internet of Things (IoT) [44-45]. It would be helpful and inexpensive to have a user-level app that works with smart buildings connected to the Internet of Things. Using a smartphone app, a person can connect multiple alarms, home security settings, and high-tech heating and lighting systems to a single hub. Automation's main goal

ISSN PRINT 2319 1775 Online 2320 787
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

is to make work easier for machines instead of people. Among other things, each of us can turn on electrical tools by saying things like "fan on" and "light on" [46].

5 IoT-Based Smart City Challenges and Solutions

Each of us talked about several different topic-based aspects of problems and solutions in the parts that came before this one that were more important. In this part, though, we will talk about some of the most common problems and ways to fix them that come up with smart cities that use the Internet of Things.

The common issues and problems when putting Internet of Things-based smart cities into action are discussed in this part [43]. According to Table 3, the smart city has problems, and there are possible answers. Addressing challenges in deploying IoT systems requires strategic solutions to ensure reliability, data quality, security, and privacy, as well as the efficient use of smart sensors, networking, and handling large-scale data.

Reliability in IoT systems can be improved by adopting decentralised and distributed architectures, enabling autonomous decision-making processes. Energy-efficient designs contribute to the system's overall reliability by ensuring optimal use of resources.

Assuring data quality involves implementing cost-effective measures and efficient data-gathering processes. Resolving potential issues with data quality is crucial, and adopting techniques that enhance the reliability and accuracy of collected data can ensure the effectiveness of IoT applications.

Security and privacy are paramount concerns in IoT ecosystems. Strategies such as preventing data leaks, implementing strong encryption, introducing new authentication techniques, and ensuring private access to sensitive data contribute to robust security and privacy measures. These precautions help protect against theft and unethical data manipulation, fostering user trust. Smart sensors play a vital role in IoT by enabling the measurement, inference, and comprehension of environmental indicators. Using low-power sensors that are highly efficient and encourage interoperability enhances the overall functionality of IoT systems.

Efficient networking is essential for the success of IoT deployments. Utilising low-power networks ensures that devices communicate seamlessly while optimising energy consumption, contributing to the system's sustainability. Handling large-scale data involves scalable and efficient solutions. Centralised big data processing centres with anonymised data for sensitive information ensure scalability and efficiency in managing and analysing vast amounts of data generated by IoT devices. Large-scale IoT systems require storage and computational capabilities to extract meaningful insights from data. Managing delays in data processing is crucial, and systems must be equipped to handle the computational load efficiently.

Table 3: IoT challenges and solutions of smart city.[4]

Paper Ref.	Challenge	Solution Reference
44	Reliability	Decentralised and distributed architectures and decision-making, Energy Efficient

45	Assuring data quality	Cost-effective, Efficient Data gathered might be resolved
46	Security and Privacy	Prevent data leaks, ensure their sensitive data has private access, use new authentication techniques and encryption, and steer clear of theft and unethical manipulation.
47	Smart Sensors	Enable measurement, inference, and comprehension of environmental indicators, Low-power sensors, and High efficiency, encouraging interoperability.
48	Networking	Low-power networks,
49	Big data	Scalable, efficient, and centralised big data processing centres give sensitive data anonymity.
50	Large Scale	Provide storage and computational capability to extract new information and handle delay.

6 CONCLUSIONS

This research is mainly about the Internet of Things (IoT) as a base for various smart city uses. New technologies related to the Internet of Things (IoT) have been growing recently. These include artificial intelligence (AI), machine learning, and cloud-edge IoT platforms with blockchain and security issues. Our evaluations included how trash is handled, smart parking, energy-efficient building systems, and energy-efficient traffic light systems. IoT infrastructure installation could open up many possibilities, followed by useful uses to make creating, enhancing, and improving daily tasks easier. This report examined new research papers on Internet of Things (IoT)-enabled smart city frameworks. This study examines IoT as a platform for smart city applications, considering upcoming technologies like AI and machine learning, cloud-edge IoT ecosystems with blockchain, and security concerns. This study investigated energy-efficient waste management, smart parking, building, and traffic signal systems. Installing IoT infrastructures can offer numerous benefits, including practical applications for improving daily tasks. Discussed the difficulties and solutions for smart cities using machine learning, including ensuring security and privacy. We examined the sustainable smart city's cloud-edge IoT ecosystems, focusing on IoT architecture, technologies, devices, and protocols. Discussed IoT applications, obstacles in designing IoT systems, and solutions to key issues like management, coordination, and blockchain technology. We presented a framework for mega events and discussed the potential and problems of future smart cities. We reviewed and synthesised the implementation of IoT-based smart cities using intelligent systems and sensors, considering recent trends in new technologies.

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