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SURVEY AND STATE OF THE ART

Smart cities: the role of Internet of Things and machine learning in realizing a data-centric smart environment

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Abstract
This paper explores the concept of smart cities and the role of the Internet of Things (IoT) and machine learning (ML) in realizing a data-centric smart environment. Smart cities leverage technology and data to improve the quality of life for citizens and enhance the efficiency of urban services. IoT and machine learning have emerged as key technologies for enabling smart city solutions that rely on large-scale data collection, analysis, and decision-making. This paper presents an overview of smart cities' various applications and discusses the challenges associated with implementing IoT and machine learning in urban environments. The paper also compares different case studies of successful smart city implementations utilizing IoT and machine learning technologies. The findings suggest that these technologies have the potential to transform urban environments and enable the creation of more livable, sustainable, and efficient cities. However, significant challenges remain regarding data privacy, security, and ethical considerations, which must be addressed to realize the full potential of smart cities.

Keywords Smart cities · Applications of smart cities · Internet of Things (IoT) · Data acquisition technology · Wireless and mobile networking · Deep learning

Arabic Keywords لمدن الذكية . انترنت الأشياء . الشبكات اللاسلكية والمتنقلة . تعلم عميق . ابتكار شامل

Introduction

The concept of a smart city is evolving rapidly as it has completely transformed how human beings and machines interact in urban settings [1]. The idea of a smart city has solved the problem of managing an increasing population migrating toward urban centers. A large part of the world's population is now living in cities. It is expected that in the future, about seven devices per user will communicate

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actively over the internet [2]. Before the end of 2050, the number of people living in cities is estimated to be around 70% of the global population. Thus, the major challenge in the upcoming decades is the strategic development of urban areas [3]. To meet the increasing demand for services with improved quality, it is essential to manage the urban environments by transforming them according to the concepts of a smart city [4]. This will revolutionize various areas of life, including transportation, health monitoring, vehicle control, waste management, etc. The smart city, by definition, is mainly reliant on the aspects such as a broad range of digital and electronics applications, embedded Information and Communication Technologies (ICTs) for administration environments, communication and information technologies in operational systems, facilitating individuals and ICTs to improve innovation and information [5]. Generally, a smart city is described as a city that comprises the applications of information and communication technologies and the execution of methods that certainly affect the lives of citizens residing in that atmosphere.

One of the most critical outcomes of smart city applications and execution is the generation of large-scale data sets. This large amount of data for integrating various algorithms related to artificial intelligence and machine learning requires significant processing. For example, nearly every single institute of medical and clinical sciences has utilized machine learning and artificial intelligence recently [6, 7]. Radiology is one of the very effective disciplines of smart health where the benefits of artificial intelligence and machine learning are applied [8]. Medical examinations and scans like chest X-rays are accomplished more than two billion times globally annually. A prominent deep learning algorithm is Deep Neural Networks (DNN), which are implemented to a wide range of health-related imageries like medical scans including bone images for breakages and fractures [6, 9, 10], sorting cardiac diseases and tuberculosis [11], scans for lung nodules [6], coronary calcium score [12], brain scans for evidence of hemorrhage [13], pancreatic cancer [14], magnetic resonance imaging [15], echo-cardiograms [14, 16], head trauma [17] and mammography [18]. Recently, many critical applications have a data-centric model, such as electricity or water resource management, verification, and payment of intelligent card services. Using smart mobility can decrease the emission of CO_2 and improve traffic efficiency. The applications of smart city and their usefulness completely relies upon the compilation of information, data connectivity, and their pervasiveness [20]. Smart cities benefit individuals and their natural environment, as shown in Fig. 1.

A smart city typically comprises smart homes, smart health, smart roads, smart parking, and smart people. Nowadays, technologists, engineers, and developers are exploring for smart IoT-based solutions to develop the suitable structural design of a smart city. Smart city implementation is based on three levels as shown in Fig. 2: (1) first of all, gather data and obtain knowledge from statistics associated with urban environments, (2) saving, manage, evaluate, and handling of information to execute independent judgments, and (3) service level implementation of the established decision [1]. The deployments of IoT-based infrastructures are evolving these days due to their substantial part in the disciplines of academics and manufacturing for smart cities [21]. The metropolitan residents are expanding gradually, creating many hurdles for civic life. In 2007, 50% of the population was residing in the urban environment, which is expected to have a significant shift by 2030 based on a forecast by the United Nations Population Fund [22]. IoT-based infrastructure is anticipated to play an important part in many applications for smart businesses and urban inhabitants.

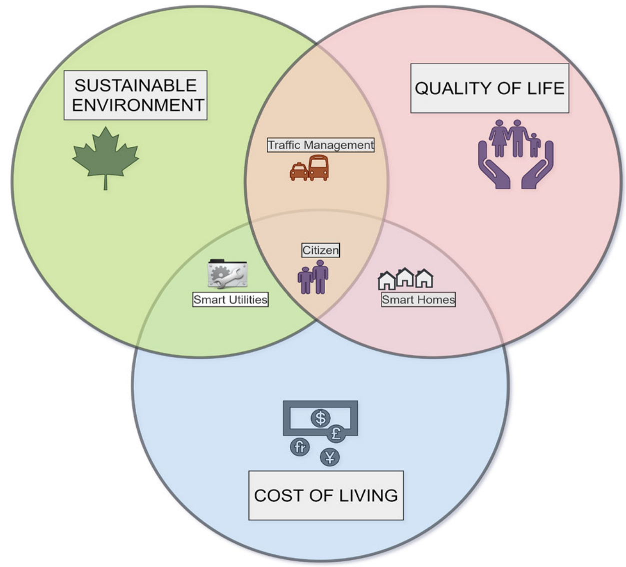


Fig. 1 The basic objectives that a Smart city aims to achieve [19]

Many recent studies have explored the role of IoT and machine learning in realizing a data-centric smart environment [23]. The connection between a smart city and IoT is explained in [24]. The study on architecture for smart city areas is demonstrated in [25]. Also there are many other good research works in the area like [26] and [27] are most recent.In contrast, the design and basic architecture of a particular smart city application like (mobile logistic application) were discussed in [28]. Distinctive deep learning calculations with video examination as an accurate smart city application were presented in [29].

In [30], a particular smart city application known as EVC (Electric Vehicles Charging) is presented with an emphasis on the minimization of air pollution and less use of resources [31]. The utilization of Wireless Sensor Networks (WSN) in smart metropolitan areas was proposed in [32]. This study is extraordinary because of its information-driven perspec-

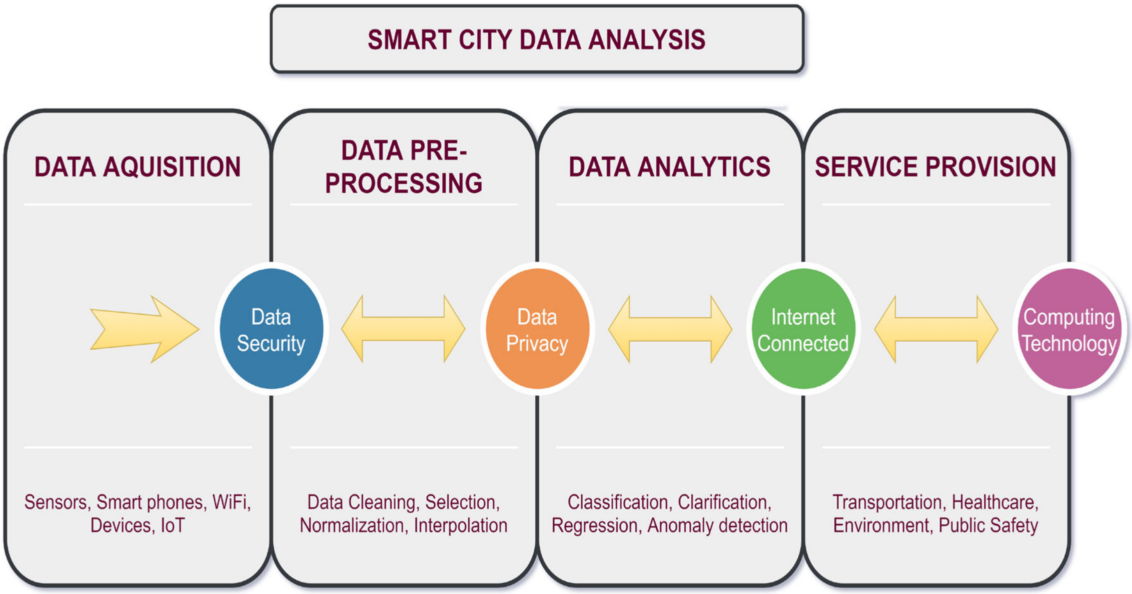


Fig. 2 A smart city data life cycle

tive of SC applications and administrations. However, one of the comparative overviews of the information life cycle regarding Traffic Management Systems (TMS) for sensitive city areas is restricted in its appropriateness to smart city development, system, and administrations [33].

The study in [34] provides an overview of the various applications and technologies that are used in smart cities. The authors examine the role of IoT in smart cities and discuss the challenges and opportunities of using IoT in urban environments. They also discuss the potential benefits of using machine learning in smart cities and highlight the need for data analytics to realize the full potential of IoT. Similarly, the work in [35],? provides an in-depth analysis of big data analytics in smart cities. The authors examine the role of IoT and machine learning in collecting and analyzing data and highlight the challenges and opportunities of using these technologies. They also discuss the potential benefits of using big data analytics in smart cities, such as improving public safety, reducing traffic congestion, improving energy efficiency, and reducing carbon emissions. The authors in [36] examine various applications, such as transportation, energy management, and healthcare. They also highlight the need for new algorithms and tools to analyze data and provide future research recommendations. All these studies demonstrate the importance of IoT and machine learning in realizing a data-centric smart environment. While challenges and opportunities are associated with using these technologies, the potential benefits of using data analytics in smart cities are significant. Future research should focus on developing new algorithms and tools to analyze data and explore new IoT and machine-learning applications in smart cities.

Motivation and contribution

The motivation behind this work is to explore the impact of IoT and machine learning technologies in creating smart cities. With the increasing population, cities face significant challenges in managing their resources efficiently and improving the quality of life for citizens. To address these challenges, cities increasingly turn to smart technologies to create data-centric environments that collect and analyze large volumes of data in real-time. Machine learning algorithms analyze this data and provide insights to help cities make informed decisions about resource allocation, traffic management, and urban planning. This review paper examines the various use cases of IoT and machine learning in different aspects of city life, such as transportation, energy management, and public safety. Additionally, the review paper will discuss the challenges and limitations of these technologies and provide recommendations for future research and development.

This will provide policymakers, researchers, and practitioners with a comprehensive understanding of the benefits and limitations of these technologies. Stakeholders can make informed decisions about their implementation and create data-centric environments that improve the quality of life for citizens while promoting sustainable development.

Although much research is in the literature related to this area to the best of the authors' knowledge, no such work presented a detailed review. This paper contributes to understanding the potential of IoT and machine learning technologies in realizing smart cities with a data-centric approach. It provides insights into the challenges that must be overcome to realize the full potential of these technologies in urban environments. The main contributions of this study are as follows:

- ✓ We elaborate on cases from different smart city application fields with a general discussion on the topics, implementations, and algorithms.
- ✓ We emphasize the importance of data in driving innovation and improvement. The paper explains how a data-centric smart environment can be created by integrating IoT devices and machine learning algorithms to collect, analyze, and act upon data in real-time.
- ✓ We evaluate an assessment of data management, containing the acquisition of data, processing of data, and distribution of data from an algorithmic viewpoint.
- ✓ We present the significant challenges that must be addressed in terms of data privacy, security, and ethical considerations to realize the full potential of smart cities.
- ✓ We consider the given framework from knowledge discovery in the machine and deep learning point of view.
- ✓ Lastly, we demonstrate the future recommendations and scope of this study.

Structure and organization

This work provides a comprehensive overview of the role of IoT and machine learning in smart cities, proposes a data-centric approach to designing smart environments and presents case studies to demonstrate the potential benefits of these technologies. The structure of current paper is organized as follows. Section "Introduction" is the detailed Introduction related to the topic with an overview of the literary work and scope considering the motivation and contributions. Section "General applications of smart cities" discusses the general applications of smart cities. Section "Various parts of a smart city" is related to the various parts of a smart city, including smart street lights, waste management systems, smart parking, smart roads, smart home, smart health, and finally, smart buildings, smart structures, and smart infrastructures. Section "Challenges in smart city" is about the challenges in a smart city. Section "Smart cities data sets and data acquisition technology" discusses the smart cities' data sets and data acquisition technology. Section "Knowledge discovery with machine learning and deep learning" is related to knowledge discovery with machine learning and deep learning which considered in detail the introduction, the architecture, hybrid methods between meta-heuristics and machine learning, and the challenges of deep learning in smart cities. Section "Future recommendations for smart cities" is on future recommendations for smart cities, and lastly, Section "Conclusion" is about the conclusion.

General applications of smart cities

This part of the study discusses the general smart cities applications [37] as shown in Fig. 3. Each of them is discussed below in this work for detailed analysis.

- **Mobility management:** This is generally related to the efficient management of the transport system of urban places. It requires and uses the information and the communication system to supervise transport. These technologies can use remote detection and video surveillance systems for managing traffic flows, pedestrians, and emergency handling. Smart mobility also requires various modes of public transport using environment-friendly fuels.
- **Environment protection:** To promote a green environment, web-based and remote monitoring are required to understand the public and green areas fully. It also requires greater environmental sustainability through better optimization and management of buildings, urban resources, and the community for energy conservation and reduction in harmful emissions.
- **Citizen welfare:** Human resources are developed to promote innovation and information technology development using a conducive learning environment. Smart learning systems enhance creativity, open-mindedness, and flexibility. Different kinds of help centers and strategies are used to explore and encourage the participation of people in public matters and solve problems.

Fig. 3 Various applications of a smart city

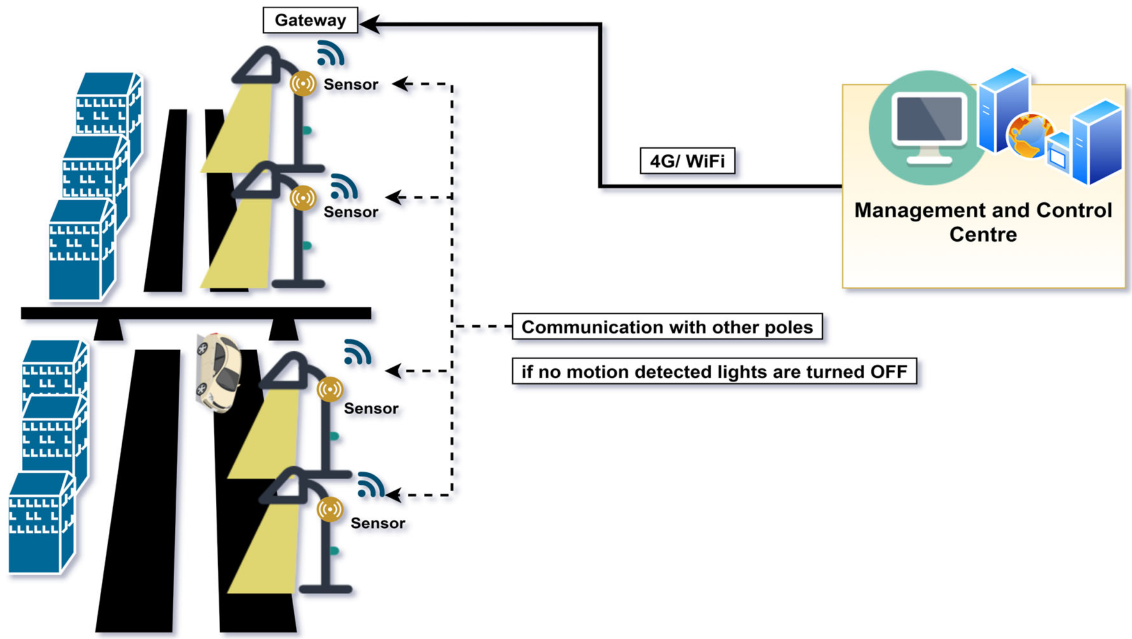


Fig. 4 Smart street light system [38]

- **Economic growth:** It requires the implementation of service and production automation schemes to accelerate the work process. Innovation and entrepreneurship create the base for new and high-end technologies, which would help maintain a city's competitiveness.
- **Smart government:** People need close contact with the government through the network and the availability of information and public services. The main objective is to strengthen the accountability and transparency of the government and better meet local community needs.
- **Public safety:** Safety and security are enhanced by using the IoT framework, which improves users' connectivity. It helps in managing homes and workplaces in a better way. The interaction with the surrounding environment is improved through ubiquitous technologies.

Various parts of a smart city

Different cities have unique characteristics, such as population density, infrastructure, and cultural differences, which may affect the implementation of smart city technologies. As a result, smart city solutions that work in one city may not necessarily be applicable to another city with different characteristics and challenges. For example, a city with a high population density may require different types of sensors and analytics tools to manage traffic flow and reduce congestion compared to a city with lower population density. Similarly, a city that experiences frequent natural disasters may need to prioritize solutions that address issues such as evacuation routes, emergency communication systems, and disaster response coordination. Therefore, it is important to recognize that smart city solutions must be tailored to the specific needs and challenges of each individual city, rather than adopting a one-size-fits-all approach. This requires a deep understanding of the local context and collaboration between stakeholders, including government agencies, private sector partners, and community organizations. In summary, it is not possible to solve all smart city problems at once, and solutions must be customized to address the unique challenges of each city. By recognizing this, smart city initiatives can be developed in a more targeted and effective manner, leading to more successful outcomes for urban residents and stakeholders.

Here we present the application and implementation of some critical smart city constituents, including smart street lights, smart waste management, smart parking, smart road, smart home, and smart health.

Smart street lights

Figure 4, smart street light is an essential application of smart cities, which makes the city smart. When we deploy smart street lights in the city, we can save a lot of energy feeding and usage of the street lights daily, depending on the daytime and the movements of vehicles and pedestrians. This saves energy and can be used in different functions. For example, this energy can be used in weather condition monitoring, temperature monitoring, or pollution monitoring [38]. The street lights must contain wireless or wired sensor nodes.

These sensor nodes will gather the essential data from the streets for effective results. This collected data can be processed within the sensor nodes of the street lights if the sensor nodes have computing capabilities. But usually, sensor nodes do not have many processors and memory functionalities. Therefore, the collected data is transmitted by a network to a control and management system, giving efficient results for the proper action. Actions may be too dim for specific street lights, or the faulty lights must be replaced. This scenario is implemented as follows:

- Smart Street Light Components: There are three main components for enacting a smart street light system in real life. These basic components are [38]:
  - (a) Smart sensors collect data from different environmental parameters. All the gathered data is sent to the control room for proper action and management. There are various kinds of smart streetlights used in the smart streetlight system. Different type of streetlights has other factors which can be preferred in different environments. Such different factors can be energy consumption, the metal used in the light structure, and the lifetime of the smart light. LEDs have greater efficiency of up to 50 percent than a standard incandescent light [39], have a more extraordinary life, and are easy to manage and control.
  - (b) The Communication network: To manage, display, and control the smart street lights, they can be connected to the control room by any communication media either through wired technology or wirelessly, i.e., Ethernet cables [40] and ZigBee [41], Wi-Fi [42], 2G or 3G or 4G [43] respectively.
  - (c) The Controller system: The control system is to maintain and manage the essential operation of the system. The control system operates to display, manage, and control the smart street lights. It monitors the energy consumption, failures, brightness level, and lifetime of different smart street lights. The brightness level of other smart lights can be adjusted and controlled according to various environmental conditions, such as weather conditions, traffic time conditions, etc. so that energy wastage can be avoided.

The issue with smart lights on streets is that they may not provide sufficient illumination or may be poorly placed, which could result in accidents. However, there are several ways in which this problem could be addressed [44, 45]

- Proper placement: Smart streetlights should be placed in such a way that they provide sufficient illumination and minimize any potential hazards. This may involve a thorough analysis of the area and consideration of factors such as traffic flow, pedestrian activity, and potential obstructions.
- Adjusting brightness levels: Smart lights can be programmed to adjust their brightness levels based on factors such as time of day, traffic volume, and weather conditions. This could help to ensure that the lights provide adequate illumination without being too bright or causing glare [45]
- Sensor-based lighting: Street lights could be equipped with sensors that detect the presence of vehicles or pedestrians, and adjust their illumination levels accordingly. This would help to ensure that the lights are only on when they are needed, minimizing the risk of accidents. Reference [46]
- Public feedback: Local residents and businesses could be encouraged to provide feedback on the placement and performance of smart street lights. This would help to identify any issues and allow for adjustments to be made as needed [44].

The key to addressing the issue of smart street lights is to ensure that they are properly designed, installed, and maintained, with input from a range of stakeholders including local residents, businesses, and city planners. By taking a comprehensive and collaborative approach, it is possible to ensure that smart streetlights are both energy-efficient and safe for all users.

Waste managing system

Managing the city's waste is essential for achieving a smart environment within a smart city. Figure 5 depicts the overview of the waste management system. Solid wastes mainly consist of garbage, residues, industrial waste, agricultural waste, electronics, etc. The composition of solid waste varies from region to region. The different waste types include recyclable materials such as glass, bottles, cans, plastics, clothes, wrappers, etc. Electrical and electronic wastes consist of wires, gadgets, TVs, computers, screens, radios, microwaves, etc. Biodegradable waste comprises food and kitchen waste such as; paper, vegetables, food items, etc. Due to the non-availability of proper disposal methods, this waste can result in environmental and health risks [47]. Some of the health-related hazards are as follows [48]:

- ✓ Skin diseases with parasitic and intestinal problems in waste collecting workers.
- ✓ Plague and flea-borne fever diseases exist in cats, dogs, and rats.
- ✓ Dust from this waste pollutes the air causing breathing problems.

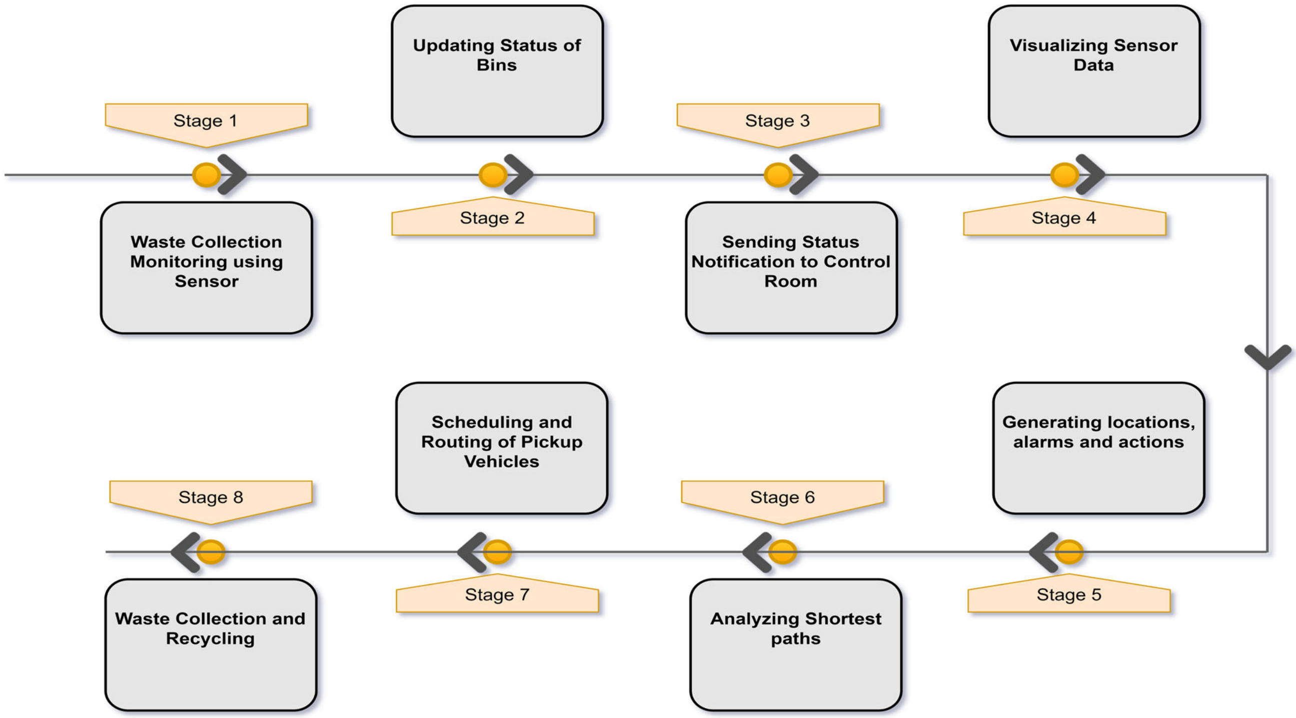


Fig. 5 An overview of the waste management system [49]

- ✓ Flies, wasps, and mosquitoes breed on these waste piles, spreading diseases such as hepatitis, cholera, diarrhea, etc.
- ✓ Mosquitoes spread malaria and yellow fever.

General description

New technologies such as smart sensors, IoT devices, ICT, and cloud platforms are continually being explored to find solutions for effective waste management [49, 50]. Such technologies will enable the shift from the waste management system to smart design. The following are some functional and non-functional requirements for the waste management system.

- ✓ Smart waste bins for collecting waste.
- ✓ Central monitoring system for management and maintenance.
- ✓ Power sources such as solar-powered batteries.
- ✓ Ultrasonic and proximity sensors.
- ✓ Micro-controller and internet connectivity.
- ✓ Waste collecting vehicles.
- ✓ GPS tracking unit.

The waste management system utilizes a set of proximity and ultrasonic sensors. The proximity sensor opens and closes the lid, automatically providing context awareness. The ultrasonic sensors provide information about the bin's capacity and fill indicators. The smart containers are connected to the central monitoring system through wireless internet connectivity, providing distributed computing. The status of each bin is monitored and communicated wirelessly without human involvement, which follows implicit human-computer interaction [49]. The waste-collecting routes and schedules are optimized using demand-responsive transport systems.

Implementation and sensors

Implementing the waste management scenario requires smart bins for waste collection, a centralized control system for vehicle routing, maintenance, monitoring, and management, and pickup vehicles for waste collection. The intelligent bins comprise several components, as shown in Fig. 6. The main chip is ESP8266, which is connected to the wireless network provided in the smart city through street lights or any other means. The sensors input the data into the microcontroller, constantly monitoring the values. As the threshold values are reached, the alert messages are generated, which are transmitted to the control center using the message queuing telemetry transport protocol [50].

- ■ Sensors: The ultrasonic sensor is used for measuring the fill levels of the bins. The main working principle of ultrasonic sensors is based on sound waves. The distance is measured by sending sound waves at some frequency and

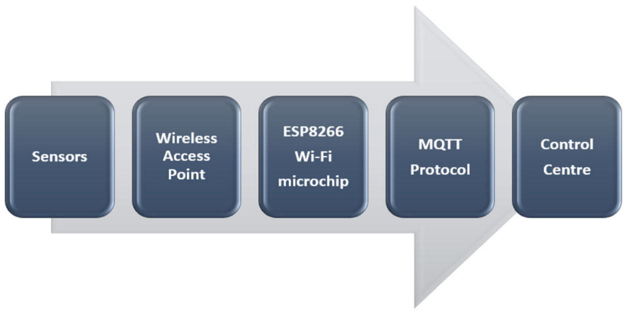


Fig. 6 Design architecture of a waste management system [50]

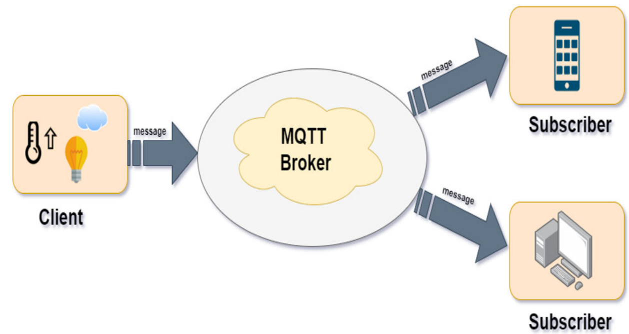


Fig. 7 Block diagram of the MQTT protocol [56]

then listening to these sounds, which have bounced back. The frequency is measured, and the difference is calculated between the sent and received signals to estimate the distance [51, 52]. A proximity device is a device that can find the occurrence of close things with no physical interaction. A proximity device usually emits a magnetic force field or a radiation beam and checks for variations within the area or bounced back signal. The perceived item is generally named because the proximity sensor's target differs completely from proximity device targets. For instance, an electrical phenomenon proximity device or physical phenomenon device may be appropriate for a plastic target; an inductive proximity device invariably needs a metal target. The device describes the maximum distance detected as "nominal distance." Some sensors have nominally altered changes, or gradually meaning that the detection distance has been reported. Several people think these processes are "sensations of hot water bottles." Due to the lack of mechanical components and the physical connection between the sensor and the detection target, the nearness device will have a high degree of functionality and a reliable lifetime [53, 54].

- ESP8266 Wi-Fi Microchip: ESP8266 is a low-cost Wi-Fi semiconductor device with a full TCP/IP stack and microcontroller function factory-made by Espresso Systems, a Chinese manufacturer located in Shanghai. This chip debuted in August 2014 with an ESP-01 module created by Western manufacturer Ai-Thinker. This compact component permits the microcontroller to link to a Wi-Fi network and build vulnerable TCP / IP connections against Hayes-style commands. However, few English documents were on the chip, and he accepted no command. Due to the meager value and unwilling fact that only some external elements of the module eventually are very cheap, several hackers searching for modules, chips, and computer code gather it. Chinese documents are also translated. The ESP8285 is an ESP8266 with 1 MB of native flash memory, which allows you to connect a single-chip device to Wi-Fi [55].
- MQTT Protocol: MQTT (Message Queuing Telemetry Transport) is a publish-subscribe-based electronic communication protocol as shown in Fig. 7. This protocol performs on TCP/IP protocol. Designed and compatible with Remote locations somewhere a "small code footprint" is needed or the network information measure is restricted. Public: A message broker is required to subscribe to electronic communication mode. Andy Stanford - Clark of Cirrus Link and Arlen Nipper wrote the preliminary version of the contract in 1999 [56]. In this specification, the meaning of "small code occupancy" or "limited network bandwidth" is not stipulated. Thus, the protocol's availability to be used depends on the context. In 2013 IBM sent MQTT v3.1 to the OASIS agency. Some laws allowed only minor changes in specifications to be accepted. Shown below is the block diagram for the protocol. A publisher sends a message to the MQTT broker, which forwards the message to relevant subscribers of that message or service [57].
- Control Centre: After collecting waste in the smart bins, the next step involves communication with the control center. ESP8266 sends the messages to the command center through the MQTT protocol. The smart bins that are filled with waste are tagged. The pickup vehicles get notified about the appropriate bins that need serviced. Another important task the control center has to perform is to generate optimal routes for the cars using algorithms such as Dial-a-ride, Genetic algorithm, dynamic programming, etc.

Smart parking

Due to the number of automobiles on the road growing, parking space has become a big problem. Locating parking spaces may be a big problem, especially in cities with many populations, places where sports and art events are held. Finding parking spaces will be an unpleasant experience. To solve this issue, several parking loads introduce sensors when the car enters and exits the parking lot, alert the driver when the driver is complete, and track capacity. This is usually a partial response to determine if the driver has free space in the parking area, but there is no exact location for these places. The prototype of an intelligent parking assistance system that employs a wireless sensor network (WSN), detects the situation of the parking space (occupied or free), and sends it to the database is discussed here. Afterward, the user accesses this data via a website or mobile application (application) and receives an update on the period. The system must provide the user with a quick update of the available parking space, but the WSN allows flexibility in sensor location. Due to the implementation of a sound parking aid system, the economic and temporal price associated with the time spent to find traffic congestion, waste of gas fuel, and parking space is insufficient due to the lack of parking space. It is significantly reduced [58].

General description

The growing population and economy have increased the number of cars on the road and grown day by day. The need for efficient, smart, advanced, and economical ways to park can be designed to allocate exact space, parking facilities, and demands efficiently. To aid the driver, there are plans to inform the driver to park some parking lots in the parking system and open the parking space. One of these universal systems has sensors in each parking space, is lightweight and can be seen from a distance. When the vehicle occupies the parking space, the light turns on by default and goes off. As a result, instead of rounding the parking area, the driver can see the position of the vacant parking area. This elementary system is suitable for drivers who are previously in the parking lot. Numerous parking support systems have been developed. The suggested system consists of the identification of vehicles in the parking areas and software parts in which users are notified about the parking information. The following are some of a parking assist system's functional and non-functional necessities.

- ✓ Ultrasonic sensors.
- ✓ Arduino Uno.
- ✓ Wireless XBee Shield.
- ✓ Gateway Device for internet connectivity.
- ✓ Database management system (MySQL).
- ✓ Webserver.

The parking assistance system consists of ultrasonic sensors to detect vehicles in the parking area. These sensors provide users with real-time data, providing context awareness for the proposed method. The Xbee device is linked with a gateway device to communicate through the internet and autonomously updates the status of parked vehicles or empty spaces [59]. The user notification system is available on the mobile device through a web server. These notifications provide implicit interaction with the system. Figure 8 shows the process flow for the parking assistance system.

Implementation and sensors

A smart parking system comprises two elementary portions: find parking and user alert. To find a parking area for a new user is accountable for determining whether a car exists in a parking spot. This task will be finished by sensors related to vehicle detection. The way to detect parking space availability may differ, but all sensors must be returned to the parking space to be empty, or the parking space is engaged [59]. The user must be aware of this information. The user's notification can inform the end-user of the state of each parking space. This can be done simply by changing the system or using the web interface.

- Sensors: The parking areas have ultrasonic sensors to detect vehicles. These sensors are controlled using an Arduino microcontroller. Arduino Uno is reading the analog values from the ultrasonic sensor. Furthermore, this Arduino has a Wireless Xbee device to connect to the internet. Xbee area unit is adept at employing many communication setups and procedures. Each XBee device can perform like a router when running XBee devices in a network arrangement. This shows the communication path between two devices, routed through multiple XBee devices [60]. Determine the shortest route and use it to preserve economic communication. All XBee devices will be wirelessly connected to the virtual entrance device, allowing access to the internet. When a serial connection to the gateway cannot be confirmed, the message is sent via another Xbee device.
- MySQL: Each device is associated with an Arduino Uno microcontroller that's successive runs on LabVIEW. This program is used for communication with the MySQL database to manage the sensor readings. These sensors need a pulse on the trigger line, so wait for the associate echo to come back on the echo line. The time until the echo comes back is used to determine the distance. The default threshold distance is used for distance comparison. The space is compared with the threshold value if it's less than the pre-defined value; it means that the parking area is not empty, and a vehicle is detected in that area. This information is updated in the database and communicated to the web server. The gateway device provides internet access as the feature is not available by default in the Xbee device. This gateway acts as a local area network connection where every device can communicate with other devices. The Xbee devices have specified identifiers assigned to them. These unique identifiers store

Fig. 8 Process flow diagram for the parking assistance system [59]

information regarding parking areas in the database. The actual value is interpreted as the occupied space, and a false value is regarded as the empty parking area.

- User notification: The information from the database is gathered and sent to a web server. The webserver is set up to deliver services to the customer by using smart devices or computers. The information in the web server is modified in real-time as the application demands. This information is accessed by users from their smartphones or web-based applications. The users can access this information from servers to find vacant parking spots. This interface can be implemented for both the plate form of Android and iOS devices. The application can be designed to notify the user about the status of parking lots.

Smart road

Intelligent transport provides a safer and more comprehensive infrastructure for pedestrians, cyclists, and various abilities. It promotes ecological mobility through well-designed sections to not interfere with the flow of pedestrians, private bike lanes, and efficient public transportation. It also helps reduce travel time, distance, accident rate, noise, and air pollution. An intelligent road, also called an intelligent highway, is a term that represents a road that uses a sensor or IoT technology that makes the driver safer and lush. Without smart ways, smart cities and driverless cars will never be smart soon. Smart roads can deliver drivers real-time information on weather, such as icy roads, and traffic information, such as traffic jams and parking availability. Smart highways are particularly useful in mountain adventures and trails to alert against traffic accidents and landslides to improve driving safety. Smart roads can also power street lights and mobile electric vehicles [61]. Controlling road conditions is essential in securing the safety and comfort of various road users, from pedestrians to drivers. In addition, the infrastructure quality information ensures that the root administrator can ensure proper maintenance. Road surface anomalies such as gaps, deceleration belts, railroad crossings, joints, etc., can identify problems of vehicles and may affect the safety of road users [62].

General description

The national road network system and road design play a vital part in economic, social, and cultural development and development. Therefore, because people with disabilities have many problems in their lives, to develop better, it is necessary to investigate road conditions, design roads and facilities for users, and inadequate investigation of road networks. Every day, some modern and innovative techniques and methods have been introduced to the previous manufacturing or construction of road information and solve all problems such as traffic jams, accidents, injury, and deterioration of road conditions. The IoT is a system of electronic things, software, sensors, and physical elements (devices, automobiles, constructions, etc.) integrated with network connections. These objects gather and interchange data [61]. The Internet of Things can detect and control objects remotely through the existing network infrastructure. Reference [63], Creating occasions to incorporate the physical world straight into computer-based systems, efficiency, accuracy, economic efficiency [62, 64].

The primary focus of this study is to minimize daily accidents and improve the rate of safe driving; for safe driving, new strategies and applications are developing. In a further study, the researchers are now finding and visualizing the current system with maximum functionality and more feature to facilitate the user more and more. Concerning elements such as node-level hardware and power constraints and specific functions, a particular set of services, including a particular system instance, is selected at the design level. We hope to provide this system and the essential information service on the state of the road [65].

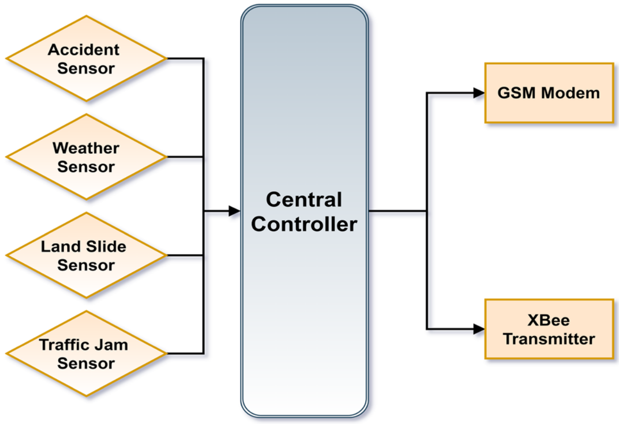


Fig. 9 Block diagram representing the basic components for the traffic management system

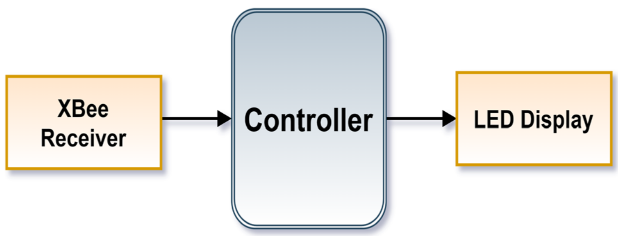


Fig. 10 Block diagram of the receiver side

Implementation and sensors

Figure 9 shows all the chief mechanisms used in smart highways. Some of the crucial features of intelligent highway technology include that vehicles can keep a trail of the longest travel time estimates. Vehicle count at intersections and pedestrian presence identification is also important.

The design considerations for the smart road include a set of sensors to detect congestion, a water sensor detector for the bridge, a slider detector sensor, an accident detection sensor, and an active and active LED display board. A general design includes multiple sensors and data-gathering devices linked to a microcontroller (Arduino ATMega 328). Incoming data from the sensor are gathered, stored, and read by this microprocessor which extracts critical information, which would be sent to using GSM and XBee (Zigbee). From 9, the transmitter contains four sensors: a microcontroller, a GSM modem, and an XBee transmitter. When something happens, a specific sensor senses it, and this information is sent to the microcontroller. The central part of the system is the microcontroller which controls all operations associated with accidents, landslides, bridge overflows, and congestion. News is sent to the ambulance and rescue team via the GSM modem. Messages from the XBee transmitter are sent to the receiver unit represented in Figs. 10 and 11. This section comprises an XBee receiver, microcontroller, and LED board.

Smart home

Smart homes provide comfort, security, and energy-saving leading to low operating costs and comfort. The term *smart home* is often used to describe homes with home applications, illumination, warming, air conditioning, television, computers, audio and video entertainment systems, security systems, and camera schemes that can interconnect with one another [66]. This would allow remote control of smart home systems from every room in the home or remote control from anywhere globally via telephone and internet. Smart product installation in homes is expected to benefit residents in comfort, time, money, and energy savings. Since most houses do not have an integrated system with various devices (for instance, high energy consumption devices), a smart- home is an economical way for homeowners to control their home systems. In recent years, automation technology has been increasingly recognized by people in home improvement and industrial and commercial fields [67].

General description

Home automation technology continually improves flexibility by combining the latest features to meet individuals' growing economic load. There are many technological advances at our fingertips, which could make our lifestyle more relaxed. The essential advantages of home automation are as follows:

- ✓ Managing Devices: Maintaining connectivity and managing devices via the smart home interface is a significant step forward in technology and home management. In theory, there is a need to learn how to use myriad functions and devices in the home using applications on smartphones and tablets. This shortens the learning time of new users and makes it easy to access the home functions they need.
- ✓ Flexible: Intelligent home systems are often very flexible to adapt to technologies such as new equipment. If we can seamlessly integrate these systems, working with the owner and updating them to the latest lifestyle technology will be easier.
- ✓ Easy to use: Due to a simple learning and implementation program, smart home technology can easily provide automation. A centralized regulator method controls the overall operation of various devices, reducing load and allowing one to operate the device with a single click of a button.
- ✓ Extra Security: Integrating safety and checking tasks into an intelligent home system may improve home security. Many options include the home computerization system that can link mobile sensors, surveillance cameras, auto-

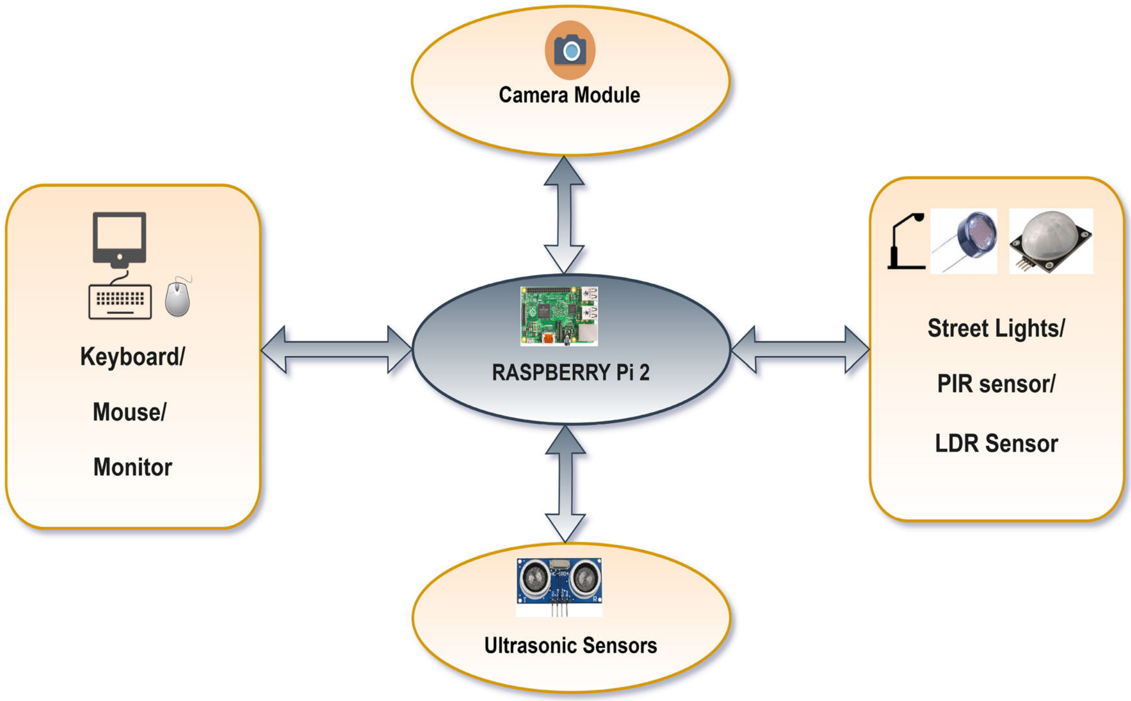
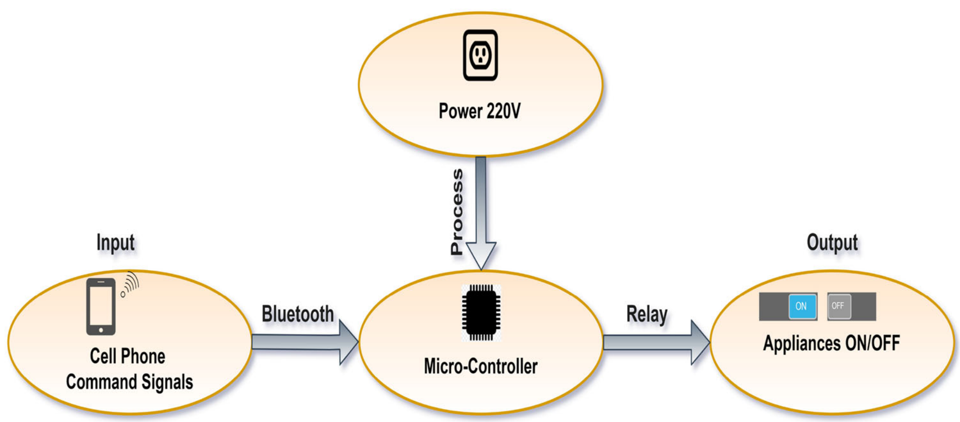


Fig. 11 Raspberry Pi 2 system for smart roads

Fig. 12 Block diagram of home automation power-controlled switch [68]



matic gate locks, and additional practical home security procedures. The system can also receive security alerts on various devices based on when an alert occurs and monitor activity in real-time, whether at home or not.

✓ Improve energy proficiency: Depending on the use of smart home technology, it is possible to create a more efficient space in terms of energy. For example, using a programmable intelligent thermostat, users can more accurately control the heating and cooling of their homes, understand the temperature schedule and configuration, and suggest the best energy-saving environment on that day. When the sun comes down, the light with the motor and the blind can enter night mode. Also, the light turns on / off automatically when entering and leaving the room, so there is no need to waste energy.

Implementation and sensors

Figure 12 represents the block diagram of a home automation power-controlled switch.

A centralized controller can be used to control appliances in a smart home. The design uses the ATMEGA328 micro-controller board as the controlling unit of the system, the Android phone as an input device, and the home appliances as an output device. The connection between the input and

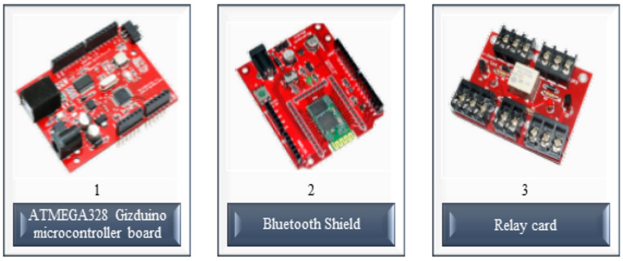


Fig. 13 ATMEGA328 Gizduino microcontroller, Bluetooth Shield, and Relay card [69, 70]

Fig. 14 12V DC Power Adapter, Jumper wires, and Android phone Blue term App [70, 71]

the control unit is wireless using Bluetooth. Figures 13 and 14 represent the components required for the design process.

A Bluetooth shield is connected to the microcontroller chip at the receiver to receive incoming signals while on the transmitter end. An Android application must send ON/OFF (1/0) guidelines to know whether the load is connected. If the app is not installed, the system does not make sense. We can also turn ON/OFF through remote wireless technology by opening the same input on the application.

Before proceeding with the project's hardware connections, a program must be compiled and uploaded in a microcontroller. The program must be appropriate to the process that you want to achieve. Figure 15 indicates the graphic illustration of this project with a single load only. An Arduino device is used as a microcontroller board.

Smart health

Smart health provides business and clinical health data, consisting of remote diagnoses, curing health records, living health services, and remote patient monitoring. Smart health can provide an effective and efficient way of health curing. For example, patient health data can be collected from different sources, improving patient health [72]. Smart health care data depends on medical devices [73] and wearables sensors that are connected [74]. Patients and citizens can get treatment through remote health services, saving their waiting and travel time [75]. Smart health consists of different entities and technologies: wearable devices, smart sensors, communication systems, etc. [76].

The Internet of things is being recognized as the most disruptive technology, which adds to the robustness anticipated with smart health in smart city services. The notion of smart health in the smart city has its foundations in artificial intelligence in combination with the IoTs, working together as a single unit. The vision of smart health in smart cities and its services is to enhance the standard and quality of daily life so that people can use technology and accomplish their most common work routine with minimal effort. The quality of life includes but is not limited to access to e-health, i.e., smart health care, ease of mobility, and near-optimal management of available resources, all considered necessary specifications of smart city services. These services render a paradigm shift and transform the traditional city into a smart city [75].

Smart buildings, smart structures, and smart infrastructures

The above sections discussed in detail the smart cities concerning smart homes, roads, and parking but lacked information about the current novel approaches that civil engineering is currently facing. This includes the challenges in deploying smart buildings, structures, and infrastructures. The improvement of the life safety requirements of citizens represents one of the most important aims of future smart cities.

- **Smart buildings:** The term can be defined as a building capable of responding according to the needs of residents, businesses, and society. Smart building is sustainable, conserve energy and water utilization, and are less polluted with emissions and waste products. It should have health, safety, and security for occupants and be capable of functioning to the requirement [77]. The term "smart buildings" is not very new and has been used for more than two decades to propose the idea of intelligent equipment, energy efficiency, and networking devices in the building. Back in the 1970s, the idea was to design buildings with energy-efficient capability, and in the 1980s, it was managed by a house PC. Nowadays, smart buildings use additional components for controlling and managing renewable energy sources, house appliances, and energy consumption using, most often, wireless communication technology. The appliances and gadgets within the smart buildings can communicate with each other and the outside environment or other buildings [78]. Generally, the smart building comprises of following components:
  - ✓ Sensors - for examining and presenting messages in case of variations.
  - ✓ Actuators - for executing a physical activity.

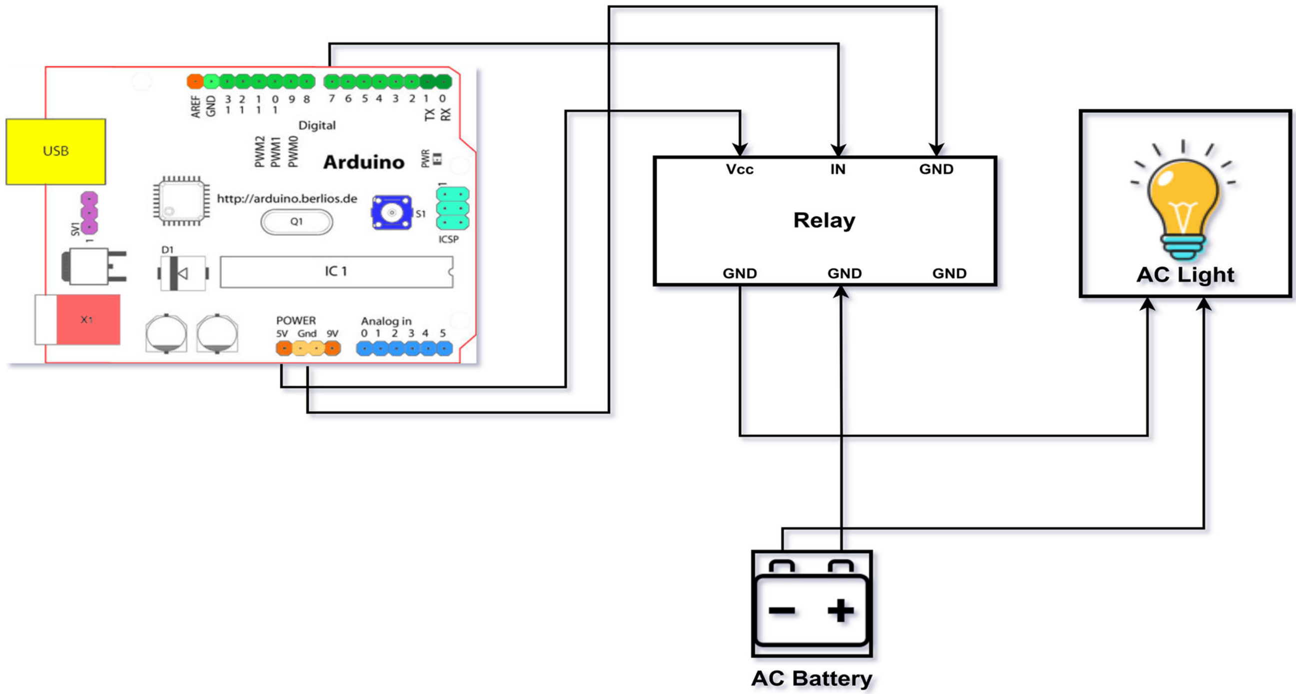


Fig. 15 Schematic diagram for connecting a single appliance

- ✓ Controllers - for managing parts and devices built on programmed regulations defined by the user.
- ✓ Central unit - for allowing programming of components in the scheme.
- ✓ Interface - for enabling the client communication with the scheme.
- ✓ Network - for permitting communication between the components.
- ✓ Smart meter - for proposing two-way real-time communication between the user and utility enterprise.

All these components create an automated building with some additional units in some cases, like power storage capacity and small-scale renewable power resources, [77]. These buildings are created and designed for the benefit of and constructed by people for individuals and the community. Efficient design management and integration guarantee that the systems and processes work effectively. Today, smart buildings can manage temperature control, airflow, and humidity in areas with harsh environmental conditions. The advances in air conditioning systems, electric lighting, and smart coating systems in buildings have eased the way of living and revolutionized civil engineering architecture.

- **Intelligent buildings management systems:** These are the most recent and novel aspects of smart monitoring systems, structures, and infrastructures. During the past few years, many buildings have been categorized as smart/intelligent, but the real applications of this term are yet to be explored with its actual capability. Intelligent buildings ensure the enhancement of business opportunities and revenue as they consider social requirements and environmental conditions for residents' well-being, leading to better work efficiency [78]. The latest intelligent building systems can connect the devices, the residents, and the systems within the buildings to provide full personal control and management. In the past few years, 5G technology has completely revolutionized the buildings, architecture, and construction business due to researchers' and academia's recent advances in 5G applications. Various enterprises, like IBM and Intel, have already conceived and advertised intelligent buildings to illustrate upcoming 5G features [79]. There are only a few studies on implementing 5G-based smart buildings, and many areas still require deep research. It is critical to realize the technical and scientific needs of the building industry as the recent 5G sector mainly concentrates on expertise and business benefits, and the end users are not considered the most substantial shareholders. 5G development has significantly improved the use of smart mobile devices with the growth of communication technologies resulting in new ideas of economic opportunities for business and industry [80].
By the year 2020 and onwards, a considerable percentage of people will be shifted to 5G facilities which approve the requirement of developing 5G-based smart cities. Smart buildings utilize the recent 5G communication and

management technologies to provide individuals with a comfortable and healthy environment [79].

The recent earthquake-related issues and studies are very important to improve the literature review for global aspects concerning future smart cities [81]. The seismic issues are aspects of critical importance concerning the overall safety level in highly-populated cities, therefore the innovative smart cities of the future bestowed with artificial intelligence-based interconnected tools may provide innovative solutions for attempting to preserve human life against natural disasters.

- **Challenges in integrating 5G-based smartness in existing buildings:** The 5G network has been established to help and encourage the population that is becoming more mobile and connected. Moreover, it will facilitate the flourishing of innovative business prototypes. However, the major challenge is to allow 5G functions in pre-existing building structural design, as the architecture cannot be altered once it has been built. Thus, renovation is a massive task in creating a smart city and incorporating an already established building into it. The volume of information to be transmitted and mobile broadband traffic will develop considerably in the upcoming years as mobile broadband is used in different situations and locations. With the help of 5G, new, scalable customer services will be created to encourage the growth of existing mobile broadband services [80]. This implies that 5G will sustain a wide range of uses, from those that require small amounts of data to those that need massive amounts of data quickly. Various network appliances, techniques, controllers, and sensors are required to make smart building residents have a relaxed and comfortable life. Therefore, in smart buildings, there is a network of remotely controlled communications [79].

Challenges in smart city

Implementing intelligent infrastructure, especially in developing countries, faces many challenges. Now we will enlighten some of these challenges. Science, technology, and innovation will help solve all the challenges.

- **Needs to find intelligent infrastructure:** Specific smart city solutions cannot merely transition from a physical location to an alternative geographic location. Intelligent infrastructure from one region to another must meet regional development needs. Environment, culture, and economy play an essential part in this procedure. Before choosing, cities should deliberate solutions to urban difficulties suitable for intelligent technologies. For example, the traditional intelligent transport system approach, including large sensor networks and data aggregation, may be too expensive to meet the needs of developing countries. A more localized and superficial intelligent Transportation System version can take advantage of the most popular mobile phone data; these data may be more suitable for developing countries. The local ITS (intelligent transportation system) community is crucial in addressing localization challenges. Some of the essential points are depicted in Table 1.
- **Skills gap:** For smart cities to succeed in their efforts, they must have human resource skills to ensure that all aspects of the city are efficient enough. For example, you must add a number or data tier to all related tasks handled by different technology providers and integrated operational departments. Human possessions expertise comprises scheduling and design, digital citizenship, data literacy, implementation, and administration. Investing not individual smart people but also in smart people is essential. Currently, few studies accurately quantify the lack of technology in developing countries. Therefore, first of all, the city must implement its analysis of technical defectsâ€some of the critical points which improve the skills gaps are in Table 2.
- **Absence of financial well-developed business model:** Intelligent infrastructure projects must combine public-private partnerships and creative funding of public and private resources. Policy, taxation, and certainty of regulation are significant in this course. Governments want to deal with these matters and grow with increasingly smart urban planning to promote private sector growth, innovation, and innovation of strategic new investment. Smart city strategic financing Infrastructure and technology investments are crucial to smarter cities. The smart city project involves multiple long-term stakeholders; risky citizens must understand its costs, partner revenues, and prices are collected before the project begins. Some of the critical points related to the lack of financial and business models are shown in Table 3.
- **Balanced governance:** Smart cities need new governance models. Efficient city smart management must balance top-down and bottom-up governance. On the other hand, the data produced by smart sensors implemented by diverse intelligence is collected. Infrastructure and policy measures (especially in emergencies) may require strong management and top-down implementation procedures. On the contrary, the bottom-up governance approach discussed in the top-down smart city application section (counting citizen-driven innovation and co-creation) defines the most innovative urban infrastructure characteristics. Therefore, the stability of these two methods is very significant. By attaining this balance, the municipal government can take advantage of the interactions of different actors (colleges, the private sector, civil society, local governments, municipalities, etc.). The information

Table 1 Promote the localization of smart infrastructure

Take advantage of local innovation	Connecting a regional innovation system consisting of entrepreneurs, local universities, and research centers is vital to solving localization challenges
Promote open data, open scientific model	To maximize the usage of open data creativities and endorse more extraordinary revolution, several municipalities and technology companies organized non-governmental hacking activities
Establish urban innovation units and living laboratories	Smart city apps can benefit from new institutions, such as the city innovation center. These innovation centers and laboratories provide a convenient demonstration platform, New ideas and concepts
Make use of regional innovation networks and global cooperation	If the city cannot conduct an urban information investigation, you can join other cities if you cannot invest or create local adaptation

Table 2 Mechanisms for addressing skill gaps

Speed up education programs in science, technology, and engineering	A large part of smart infrastructure creation/ generation, and maintenance, there needs to be a good foundation in science, technology, engineering, and education mathematics. The smart city Agenda offers another cause to hasten and propagate education in these areas
Transformation curriculum and promote multidisciplinary learning	Primary and Secondary Education requires curriculum reform, higher education institutions, technical occupational education, and exercise to incorporate the special skill requirements of intellectual Infrastructure. Multifaceted phenomena characterize an important smart city. Designing an intelligent and innovative infrastructure requires multifaceted teamwork
Contribute to high technology organizations to train smart city workforce	Private companies actively participate in the development of smart and new city solutions, Inventive, smart applications. On the personal side, people can join the company to provide a lot to provide your staff with the necessary training

key is the most significant cause of failure in the integration of technology and management for the development process of a Smart City. The governance model needs reform to get the data from its Infrastructure that can be effectively utilized in decision-making [82]. City administration executives face the challenge of designing new ways. Put citizens' needs into the governance process to achieve the method by fully balancing top-down and bottom-up governance techniques. Several critical points related to the overall balancing act of governance are in Table 4.

- **Design inclusive smart city:** Additional main trial facing the smart city idea is a commitment to all citizen groups and promoting inclusion. Smart City applications should be Inclusive to provide opportunities for all and ensure that specific groups have neither been excluded from the positive influence nor disproportionately affected by the social costs. It can be compulsory. For example, the requirements of helpless clusters such as women and the aged person with in-capabilities should integrate into the smart city strategy. It is crucial to ensure that these vulnerable groups are included because they are deficient in the talents to practice smart city apps, or their skills are lacking livelihoods may be affected by smart city applications. The promotion of participation in urban governance is essential for the progress of an entire smart city. This section introduces some necessary policy tools.

Table 3 The absence of the financial and well-built corporate model

Develop innovative technology-driven financing models	Smart city apps can increase efficiency to reduce excess assets. If productivity advantages are dignified by suitable intelligence technology and business model monetization and then become part of the smart arrangement, share costs can be rewarded for this benefit
Valuable data	The data generated by the smart Infrastructure can be converted by the city government to produce new knowledge, generate revenue, and sell it to various investors. The fundamental is to create the appropriate value chain for multiple levels of data relevant to this data and business model
Produce financial need from existing resources by more intelligent use	An online platform can help stagnant pools of public resources and create additional revenue for all countries. Finally, the concept of cleverness can promote the further practical use of available properties and deliver original bases of income city

Table 4 Balanced governance in the smart city

Promoting Bottom-up participatory governance platform	Numerous advanced and technology presentations offer a platform the city government can interact with citizens regularly. The city's government is currently actively using various media and innovative technologies citizens are managing in the city
Break down of administrative and storage place to create smart city operation	The data and information generated by Smart City are collected through the infrastructure components of public services and public services and are generally managed by different government agencies. Cities cannot utilize the data gathered by decomposing the management storage towers of these entities more effectively

Table 5 Design inclusive smart city

With the help of Smart city to formalize the informal sector	In most countries, there is a lack of data on the informal sector and informal settlements. This is why they are often excluded from urban planning and projects
Give reasonable infrastructure for the informal sector	One of the main features of the informal sector is the lack of traditional public services such as water and electricity distribution. However, intelligent infrastructure can design applications that make these essential utilities available to the human department
Make smart cities more gender generally	Infrastructure strategy; first, it can intervene and run a platform for city developers to cooperate with women to recognize their desires. Second, it can improve the analysis of urban women's problems and use data in real time
Develop smart infrastructure for all vulnerable groups	Innovative technology ensures that smart cities are inclusive even for the elderly (who often have limited flexibility) and people related to it disabled

Table 5 presents some of the points related to the design of an inclusive smart city.

- **Sensory overload:** Smart cities are founded on data with sensors for data acquisition. This is not like a road, but buildings and street lamps awaken like magic and start chatting. The name needs a sensor to listen, sniff, and feel. The stage can collect all data and create decisions (or recommendations) at a rate that exceeds the labor force. The sensor measures temperature, traffic pattern, human flow, air value, and infrastructure honesty (e.g., is the bridge harmless?) Research, innovative research, and consultancy companies plan to introduce 1 billion sensors worldwide by 2020.
- **Quick approval and clearance:** This is something given. It will take time to obtain approval and approval from government agencies. This needs to change in expanding smart cities that use extensive data and the IoT. The project has a deadline. You need to get approval and approval in as short a time as possible so that the project can maintain its pace. The state government must cooperate to speed up the approval process. If necessary, it can automate the entire approval process online. A board of directors can be established to manage the approval of services such as water supply, sewerage, drainage system, telecommunication line, cable, etc.
- **Human made resources:** Human resources mean staff and employees who need to implement the project in this case. There is a high demand for skilled occupational workers. Building 100 smart cities is not an easy task (some cities need to start from scratch). The workers employed in this project must be appropriately trained. The challenge is that only a limited budget is allocated for training and skill improvement.
- **Update an existing city:** Updating the city is not too easy as we think; it requires a lot of infrastructures and financial help. It requires adding features to the existing setup to make it more efficient. One of the central government's plans is to turn small and big cities into smart cities. The task is to study urban planning that more than 80% cities cannot offer. Therefore, the investment left by the central government is insufficient to start. The following section outlines some techniques for retrieving data from intelligent systems and examines several policies implemented from a smart city perspective.

Smart cities data sets and data acquisition technology

Data sets for smart cities

An informational index is the growth of information. Usually, information collection is compared with individual database tables or individually measurable information grids. Specific variables are described in each part of the table, and each line is associated with a particular individual in the related information set. Relevant information concerning each element of each collecting information like the height and weight of the question is recorded. Each point is called a reference point. The informational index may involve information for at least one individual, compared to the number of columns. Information gatherings that are great to the point that regular information-preparing applications are deficient in managing them are called ample information. Reference [83] is the open information teach; a dataset is an element to quantify the data discharged in an available information store. The European Open Data entryway totals a more significant portion of a million datasets. Reference [84] in this area, diverse descriptions have been projected [85], yet as of now, there isn't an official one. Certain dissimilar subjects (ongoing information foundations [86], non-social datasets, and so forth.) expand the anxiety to attain an accord around it. A little quality illustrates an informational collection's erection and possessions. These integrate the amount and sorts of the features and altered truthful actions relevant to them, such as standard deviation, and kurtosis [87].

- **Overview of prior efforts:** This section provides detail of the most widely used datasets for smart cities and overviews state-of-the-art papers which used these datasets to get formal results. Barely any significant datasets portray their attributes.
  - Wallflower dataset: This is a genuinely understood dataset that continues being utilized today. It contains seven recordings, each speaking to a particular test, for example, brightening change, foundation movement, and so on. Just a single edge for every video has been marked [88].
  - PETS: The Execution Assessment of Following and Reconnaissance (PETS) program assessed visually following and observation calculations. The program has been gathering recordings for established researchers since 2000 and now contains a few dozen recordings. A significant number of these recordings have been physically named by bounding boxes to assess the execution of the following calculations [89].
  - CAVIAR dataset: This dataset includes over 80 indoor schedule recordings that can be used for conversations with a wide range of human activities, such as walking, reading, shopping, and fighting. As with the PETS dataset, a jump frame is related to every emotional appeal [90].
  - I-LIDS dataset: This dataset comprises four situations (stopped vehicle, surrendered protest, individuals

strolling in a confined zone, entryway). Because of the span of the recordings (over 24 h of film), the tapes are not wholly named.
- ELISEO dataset: This dataset encompasses other 80 video clasps of different indoor and open-air scenes. Hence, reality primarily comprises abnormal state data, such as the jumping box, question class, occasion write, etc. The dataset is more reasonable for order and occasion acknowledgment than altered identification.
- VSSN 2006 dataset: This dataset encloses nine semi-engineered recordings of a genuine foundation and misleadingly moving items. The tapes contain energized foundation, light variations, and shadows; though, they incorporate no casings drained of action.
- IBM dataset: This dataset contains 15 internal or external PETS 2001 or extra records. One of 30 indicates a jump box around each movable element near the view for every video.

- **CDnet dataset:** The Cnet dataset exhibited at the IEEE Change Detection Symposium contained 31 records, including ship, automobile, truck, and scenes inside and outside of people walking in various challenging situations. These records are taken by several low-resolution IP cameras, medium-resolution cameras, and PTZ cameras that heat the camera. As a result, the spatial resolution of the Cnet record changes from 320×240 to 720×576. Besides, different illumination conditions and pressure parameters change the level of disturbance and pressure disturbance from one video to the next. Recording time ranged from 1000 to 8000 h. Recordings taken with a low-end IP camera were incompletely affected by long-term adverse effects. We believe that the way records fall within a specific range will help bias this data set to a particular group's progress positioning technology. According to the history of each test, papers are divided into six categories. The purpose of recording selection is that one type of testing is one of the categories. For example, only records in the "shadow" category contain solid shadows, and documents in the "dynamic background" category contain the parasitic motion of the concrete on the ground. Such a conference is fundamental to identifying the quality and disadvantages of various change discovery strategies. The creator captured each video in addition to the video in the "gauge" category of the PETS 2006 dataset [91].

Data acquisition technology

A major challenge in engineering and natural science research is collecting and analyzing large environmental and natural phenomena datasets. For this purpose, complex systems based on sensor networks are used. These systems, also known as data acquisition systems (DAQs) [1], are often equipped with many sensor elements to offer information about the environment and are accessible via the Internet. The use of these systems for educational purposes includes using systematic processes of information gathering and analysis to explore, describe, explain, or predict educational phenomena to create new teaching methods [1]. Now, we outline the multiple techniques and skills for data attainment. These technologies consist of IoTs, sensor networks, Mobile/Vehicular Ad-hoc Networks, Device-to-Device, and 4G. We also present the previous work which used such skills in the background of intelligent cities in tabular form.

- **Internet of things:** IoT is a network of physical devices, automobile devices, and additional components integrated with electronic components, software, sensors, actuators, and connectors that allow these objects to join and interchange data [92]. IoT applications are launching innovative city programs globally. It provides remote monitoring, management, and equipment control and creates new knowledge and actions from massive data stream real-time information. The central characteristic of a smart city is the degree of integration of information technology and the general application of information assets.
- **Sensor networks:** The sensor network contains a small set of devices driven by batteries and wireless Infrastructure that monitors and records every environmental condition from the factory to the data center, hospital laboratory, and even the field. The sensor network is connected to the Internet, the enterprise's WAN or LAN, or a dedicated industrial network and can send the collected data to the analysis and application program backend system. Extensive sensor networks (environmental checking, waste administration, health observing, smart grid, etc.) have become essential for gathering intelligent city data. Several sensors (motion sensors, cameras, sensors to manage environmental constraints) have been introduced [19]. The main challenge of the sensor network is to deliver appropriate semantics for varied data used in diverse smart city applications rather than placing a vast number of sensors in cities. Sensor networks are one of the critical technologies for data acquisition [93].
- **Mobile ad-hoc networks (MANETs):** Mobile Ad-hoc Networks (MANETs) is a network that does not contain the Infrastructure for mobile devices, and they interconnect with one another without a physical medium [102]. The critical trial is to preserve the information needed for the correct route [103]. Evaluate MANET's different routing protocols for VoIP, HTTP, and FTP applications in a smart city environment. Vehicle Ad-

hoc Networks (VANETs) deliberate in the situation of intelligent transportation and intelligent transportation systems. Meanwhile, VANET is a particular type of MANET, and difficulties affecting MANET also affect VANET's data collection process. VANET uses various apps to gather data and offer to clients to serve them [104]. These applications are divided into security and information entertainment applications. Safety applications used to advance road safety, i.e., frontal collision warnings and information and entertainment applications, are designed to provide comfort and entertainment for vehicle occupants, such as traffic information and weather information [105].

- **Device-to-device (D2D):** Device-to-Device (D2D) communication in a cellular network is defined as a serial connection and communication between two mobile users without going through a base station (BS) or core network [106]. In traditional cellular networks, all communications must pass through the BS even though both parties of the conversation are in the D2D communication range [107]. This architecture is suitable for traditional mobile services at low data rates, such as voice calls and text messages, which are often not enough for users to communicate directly with each other. However, users of mobile devices in current cellular networks use high-speed data services (e.g., video sharing, and games). D2D refers to a wireless communication technology in which the device can interchange data openly without traversing base stations [106]. Non-infrastructure facilities can profit significantly from D2D communication. One possibility is to provide a secure connection if the Infrastructure is damaged. With the increasing number of mobile devices and IoT devices in the city, 4G plays an essential role in smart city applications. 4G is helping in the data acquisition in the smart city and the deployed intelligent towns. The work in [108] studied and used a hybrid of 5G/4G/3G, IoTs, and D2D for data gathering in smart cities.

Knowledge discovery with machine learning and deep learning

As discussed earlier in the data acquisition section, we collect a massive amount of heterogeneous data. From this vast amount of data, one of the vital challenges is knowledge discovery, and pattern [109]. Multiple techniques and frameworks are used for knowledge discovery in the perspective of smart cities to address the smart city challenges. Here we generally debate the machine and deep learning frameworks and techniques for knowledge discovery.

Introduction to machine learning and deep learning in smart cities

- **Machine learning:** Machine learning is generally divided into two types: supervised and unsupervised learning and reinforcement. In supervised learning, the computer gives an example input provided by the "teacher" and its expected result to learn the universal instructions for mapping input to output. The input signal may be merely partly accessible to precise comments in a particular case. In unsupervised learning, tags are not given in a learning algorithm, leaving only the label to discover the structure in their input. Unsupervised learning can itself be a goal (a hidden pattern of finding data) or a means of achieving it (learning function) [110, 111]. This pre-processing step can meaningfully advance the results of the following machine learning algorithms and is known as feature extraction [112]. There is no result (i.e., classification) of training data in intensive learning, which is true in many smart city applications, but the right choice of behavior is rewarded [109].
  The utmost significant contests and limitations in machine learning are determining applicable data sets from the enormous amount of smart city data collected by data acquisition techniques (discuss above). The gathered data is now trained to fulfill the essential needs of the application. For example, measuring (the movement of people, object features, and the changes in the city with the development) requires covering these dynamic features. These data sets generate significant encounters for the administration, collection, and withdrawal of public data.
- **Machine learning algorithms:** Machine learning is additionally divided into various algorithms based on varying problem perspectives. It includes clustering, instance base, and decision trees, which help solve complex problems [110]. These algorithms are supervised and unsupervised learning. For example, public data can be grouped using mutual properties k-means and k-medians algorithms. Instance-Based is the type of supervised machine learning which trains data. With this metric, the algorithms treasure the best and most accurate match for the novel data. k-Nearest Neighbor and Self-Organizing Map are examples of instance-based supervised machine learning algorithms. Indecision tree methods form a tree shape structure for decision-making based on fundamental values. With new data, the tree traverses the whole tree for the accurate result until a final decision is reached. Speed and accuracy are the advantages of these algorithms [112]. Examples of tree methods are classification and regression trees. There are many more machine learning algorithms; some of them are summarized in Table 6.

Table 6 A summary of related work using machine learning algorithms

Machine learning algorithms	Data processing tasks	References
K-nearest neighbors	Classification	[94, 95]
Navies Byes	Classification	[96]
Linear regression	Regression	[95, 97]
Classification and regression trees	Classification/regression	[95]
Random forest	Classification/regression	[98]
K-means	Clustering	[99–101]

- **Machine learning and smart cities:** Machine learning is the only field used widely in smart city deployment. Machine learning extracts meaningful information from the massive amount of smart city data [100]. Analysis of big data in smart cities needs techniques using machine learning. Machine learning helps clean the data, and various techniques help train the data. Oriented data work as a learned system. These oriented systems help develop better smart cities, capable of predicting the need for resources to manage the growing demand of the population the machine learning technique used in the health care system. A better healthcare system is a vital requirement of smart cities. Some of the deployed system in the different towns for real-world data processing is mentioned below in Table 7.
- **Deep learning:** Deep learning is a particular machine learning type that expresses the world as a hierarchy of nested concepts, achieving high power and flexibility. Each idea is associated with a more straightforward concept and a more abstract representation. The promise of deep learning is not that the computer starts thinking like a human being. It is like trying to change an apple to an orange. Instead, suppose a sufficiently large dataset, a fast enough processor, and a reasonably sophisticated algorithm. In that case, the computer can complete the tasks that once remained in the human perception world. Deep Learning, such as Artificial Neural Networks (ANN), is successfully applied in applications such as information retrieval [127], image recognition, object tracking, and language processing [128, 129]. The whole objective of Deep Learning is to solve problems characterized by High dimensionality, which has no rules. In recent years, advances in hardware, software, and integrated systems enabled billions of smart devices to connect to the Internet. This ecosystem is jointly called the Internet of things. Many people are actively moving to cities, and primary resources become increasingly short. If everyone wants to support it, cities must manage Infrastructure such as water, electricity, and transportation very effectively. But how do you do this: the quality and format of the collected data will change, and its practical use will be hindered. For this, we will discuss several structural attacks.

Deep learning architecture and implementations

Deep learning architecture has existed for over 70 years, but new graphics and architecture processing units (GPUs) put artificial intelligence at the forefront. Over the last two decades, a learning framework has dramatically expanded the number and types of problems that neural networks can solve. This survey paper explains five different kinds of deep learning architectures. Among all the deep learning architectures, Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNN), Deep Belief Networks (DBF), Long Short Term Memory (LSTM), and Gated Recurrent Unit (GRU) are the highlights of the history of deep learning. Deep learning is not a single approach, but it's a class or group of algorithms and topologies that you can apply to a broad spectrum of machine and artificial intelligence problems. Moreover, DBN, RNN, and CNN, other deep learning architectures, include Deep Stacking Networks (DSN) [130], which are used for classification and regression of images and language [131, 132] Deep coding network (DPCN) [133] a predictive coding scheme which predicts the representation of the layer by using a top-down approach, and so on [134].

- **Artificial neural network:** A neural network comprises an input and output layer, which in most cases, includes implicit layers and converts the information to inputs that the output layer can use. It is a better tool for discovering too complicated and awkward patterns for human programmers to separate machine recognition and teach. An artificial neural network may be best known among all bio-heuristic computing technologies, as most people have at least a question of whether they understand their work roughly.
- **Convolutional neural network:** Convolution Neural Networks (CNN) are like standard Neural Networks. It comprises neurons with learnable weights and biases, which help classify the input into different layers. An artificial neural network may be best known among all bio-heuristic computing technologies, as most people have at least a question of whether they understand their work roughly. Unfortunately, most programmers are afraid to find a simple neural network to sit and work on.

Table 7 A summary of literature survey related to deployed systems

Smart system	Purpose	Description	References
Convert electrical grid data to model	Forecast the hazard of failures for components and schemes	Purpose of predicting the risk of component failure and the system. These models can be used directly the energy company first attended to Maintenance and repair work	[113]
Traffic flow optimization	Prediction of the most acceptable path for a customer with a specific target	Use to find the best route for the specific point where the user can require it	[114]
Energy efficiency of the buildings	Smart city planning	Calculate building energy efficiency to plan a smart city	[115]
Securing the metering infrastructure	To ensure the meter in a smart grid system	The security of the meter is essential as the government policy by this system the smart grid system secure the metering infrastructure	[114]
Distributed machine learning for clustering	Process sensor data	A disseminated machine learning method that routes the information where it is gathered	[116]
Location prediction	Guess your location	This will decide based on probability	[117, 118]
Adaptive arrangement and offloading	MANETs	Instance-based learning to evaluate an online adaptive scheduler for mobile offloading	[119]
Data dissemination in MANETs,	Use MANETs	The method employs a machine learning system for estimation of the novelty probability, and the machine learning system is progressively trained by received data items	[120]
Packet prioritization in VANET	VANETs	Vehicles judge the relevance of incoming information items and use them as training examples for Naive Bayesian learning and the learned logistic regression model is then used in a simulated VANET environment	[121–123]
Grid utility domain	Use of electricity for the city and neighbor areas in IoT	Utility companies must better understand the use of electricity in cities and communities to evaluate the supply and demand of additional loads	[124]
Semantic framework	Integrates the IoT with machine learning for smart cities	This framework retrieves and models urban data for certain kinds of IoT applications based on semantic and machine learning technologies	[125]
Water management system	To manage the water system for proper use in India	The use of machine learning algorithms and IoT devices for a water management system in India	[126]

CNN combines artificial neural networks and discrete convolution for image processing, automatically extracting features. So, it is specially planned for the recognition of 2D data, such as pictures and videos [135]. The neural network (NN) entails a set of neurons linked by edges. The central function of the neural network is to gradually execute complex operations on the gathered data and use the output to resolve the issue. NN is used for altered applications such as character recognition, image compression video processing, and the like. CNNs are preferred for the reasons such as the simplicity of their training process, fast running in a test phase, and ease of application among Deep Learning Algorithms. CNN consists of 5 different stages.

- Input layer: It creates the input data of the system. In the proposed method, the outputs of the Big Data Map-Reduce process will make the CNN entry for smart city management. The use of outcomes after the Map-Reduce process in Deep Learning training will ensure that the training data does not contain any inconsistencies and that a model that characterizes the learning model very well will emerge [135].
- Pooling layer: These layers can find many features in the image and gradually generate higher-order features. The convolution network can include local or global convergence layers that couple the output of a neuron cluster into a single layer and form a single neuron in the next layer [136].
- Convolutional layer: It is also called subsampling. The convolution layer implements the input and sends the output to the following layer. Convolution simulates the reaction of individual neurons to visual stimuli.
- Connected layer: It is the last layer before the output layer. Convolutional and Pooling layers in CNNs can be recursive. It is selected in the desired number. It is essential that underfitting and overfitting do not occur on the network. Fully connected layers connect every neuron in one layer to every neuron in another layer.
- Outputs: It is the output layer as the number of classifiers. System output can be a linear classifier or predict rate for a class depending on the learning model. The convolution and combination layer can decrease the number of parameters of the source image by merely extracting the characteristic. Nevertheless, to create the last result, you must smear a fully connected layer to produce results equivalent to the number of classes required [137].

■ **Recurrent neural networks** Humans never think from the beginning every second. Read this article and understand each word based on the understanding of the previous word. You will not lose everything; you will rethink from scratch. Your thoughts will last. The primary strategy of RNNs is to process the Sequential data. Like CNN, the RNN is also the traditional feed-forward neural network model. First, data is used as an input and flows through the hidden layer, and then the last layer is the output layer.
It is dissimilar from other feed-forward networks in its capability to direct information over time steps. The neuron is not connected to this layer. The drawback of this architecture is not solve all the problems related to the neural network. The main reason is that when we use many data as input if this data has any relationship, it cannot solve the scenario [138]. For example, if we write a paragraph, all the words depend on one another, and no word can be independent of the article. As we look back on history, these networks are challenging to train. Still, research, network architecture, optimization, graphics processing unit (GPU), and parallelism have become more accessible for experts [139]. Circular neural networks are trained such that the output of each time step produces a sequence based on the input of the current information and all previous time steps. Frequently, recursive neural networks use an algorithm called back-propagation through time (BPTT) to calculate gradients.

■ **Gated recurrent unit (GRU):** The GRU has two doors: a resume door r and an update door z. Automatically, the reset gate regulates how the new entry is combined with the previous memory, and the update gate defines the quantity of the last memory. Setting all the resets to 1 and updating the doors to all zeros returns you to the standard RNN model. The basic idea of learning long-term dependency using the gate mechanism is the same as the basic idea of LSTM, but there are some crucial differences. Closed repeat unit (GRU) [140] is a controlled RNN with characteristics analogous to LSTM. Nonetheless, there are some variances. There are no separate memory units [141] in the GRU, rather than three gate layers. There are only two gate layers, restart and update. The closed-loop unit (GRU) introduced in 2014 is the activation mechanism of the recurrent neural network [141]. Its polyphony modeling and voice signal modeling performance is similar to long-term, short-term memory. A closed repeat unit is a somewhat simplified variant of LSTM. Combine the oblivion and entrance door with an "update door" with an additional "resume door." The final model is simpler and more popular than the standard LSTM model [140].

Hybrid methods between metaheuristics and machine learning

Yes, hybrid methods between metaheuristics and machine learning are becoming increasingly popular in many fields, including smart environments and healthcare [152]. Metaheuristics are optimization techniques that are often used for finding approximate solutions to hard problems. On the other hand, machine learning is a field of artificial intelligence that focuses on developing algorithms that can learn from data and make predictions. By combining these two approaches, we can create hybrid methods that can leverage the strengths of both techniques to achieve better performance [153]. For example, we can use metaheuristics to optimize the parameters of a machine learning algorithm, or we can use machine learning to guide the search process of a metaheuristic algorithm. In the context of disease prediction, for example, hybrid methods can be used to improve the accuracy of traditional machine learning algorithms by incorporating metaheuristic techniques such as genetic algorithms or simulated annealing. These methods can help to optimize the parameters of the machine learning model and improve its performance in predicting new cases of a disease. The study [152] explores the application of a hybrid method that combines machine learning and a metaheuristic algorithm called beetle antennae search (BAS) to predict COVID-19 cases. This study uses data from the COVID-19 outbreak in Iran to evaluate the performance of the proposed hybrid model. The authors compare the performance of the proposed hybrid model with other machine learning algorithms such as decision trees, random forests, and support vector machines (SVM). The results of the study show that the proposed hybrid method achieves better results in terms of prediction accuracy compared to other machine learning algorithms. The authors also conduct sensitivity analysis to assess the robustness of the proposed hybrid method. Overall, the study demonstrates the potential of hybrid methods between machine learning and metaheuristic algorithms to improve disease prediction, specifically in the context of COVID-19. The achieved results suggest that this approach has the potential to be applied to other disease prediction problems as well.

Other applications of hybrid methods in smart environments include optimization of energy consumption in buildings, traffic management, and resource allocation in wireless networks. By combining metaheuristics and machine learning, these methods can provide more effective solutions to complex optimization problems that are difficult to solve with traditional methods [154]. Overall, hybrid methods between metaheuristics and machine learning are promising areas of research with many potential applications in smart environments and healthcare. As these methods continue to evolve and improve, they are likely to play an increasingly important role in improving conditions and solving complex problems in these fields [152].

Challenges of deep learning in smart cities

Technological advances in hardware, software, and integrated systems have enabled billions of intelligent devices to connect to the Internet. This system is mutually stated as the Internet of Things. The largest population is moving to cities, so the main problem is the lack of the necessary resources. If you want to support everyone, cities must manage water, energy, transportation, and other Infrastructure very efficiently. But how do we do this? The data gathered varies in quality and format, which is very hard to use efficiently [130]. The goal here is to make the Infrastructure smarter to effectively use the contracted resources. They want to use modern technology to solve many pressing problems, such as waste of water, energy consumption, traffic jams, etc. [130]. Building a more innovative city will help them solve all these problems, which will bring positive economic benefits. This will create a more efficient and sustainable living environment for people. This, in turn, will attract more citizens and companies to these cities. As we see here, this cycle is beneficial for the town's economic growth. We use the example [130] to break the term deep learning. Some of the applications of deep learning in diagnosing health-related diseases are shown in Table 8.

The artificial intelligence healthcare space is continuously expanding. The United States government invested approximately 1.1 billion in the development of AI-related technologies in 2015, as estimated by the National Science and Technology Council's Committee on Technology, and this amount will be continued to increase in the future [147]. Artificial intelligence and machine learning are steadily gaining popularity in the healthcare industry worldwide. Multiple Medical specialists have applied AI and machine learning algorithms for different disease diagnoses. However, AI and machine learning technologies are advancing continuously, but their practical implementation in healthcare has not yet become widespread [155]. Deep learning is state-of-the-art and one of the most critical types of machine learning techniques with many applications in healthcare. One of the most significant features of deep learning is the automatic extraction of features from big data without the manual selection of parts. Due to this critical characteristic, deep understanding has better results than conventional techniques in many domains such as natural language processing, cardiac diseases classification, voice recognition, and computer vision [156]. Deep Learning was initially applied to the analysis of medical imaging. The performance of deep learning was very much better in detecting various health conditions such as brain tumor detection, tuberculosis from chest images

Table 8 Applications of deep learning in the diagnosis of different health-related diseases

Work	Applications	Methodology	Ns	Performance
[142]	Detection of tuberculosis	Convolutional neural network	4701	Accuracy = 62.07%
[143]	Detection of tuberculosis	Convolutional neural network	138	Accuracy = 82.6%; 92.6% AUC = 84.7%; 92.6%
[144]	Detection of multidrug resistance tuberculosis	NN (neural networks)	280	Sensitivity = 95.1%; specificity = 85
[145]	Detection of hypoglycemic episodes for type 1 diabetes children	NN (neural networks)	16	Sensitivity = 78%; specificity = 60%
[146]	Predicting the development of liver cancer in type 2 diabetes	LR (Logistic Regression); NN (neural networks)	2060	Sensitivity = 75.7%; specificity = 75.5%
[147]	Identification for Alzheimer disease and mild cognitive impairment	DCNN (deep convolutional neural network)	142	Alzheimer disease: sensitivity = 85%, specificity = 82%, accuracy = 85%; Mild cognitive impairment: sensitivity = 84%; specificity = 81%, accuracy = 85%
[148]	HB (heart beat)	NN for FF (fiducial features)	17	OA (Overall Accuracy) = 95%
[149]	HB (heart beat)	CNN for NFF (non-fiducial features)	47	Se = 96.71%, Sp = 91.64%, OA = 93.47%
[150]	HB (heart beat)	NN; SVM (support vector machine) for NFF	48	Se = 98.91%, Sp = 97.85%, OA = 98.91%
[151]	Retrieval of medical images	DCNN	7200	AP (%) = 99.76, AR (%) = 99.77, F1 measure = 99.76
[151]	Histogram of gradient (HoG)	NN	7200	AP (%) = 74.0, AR (%) = 76.7, F1 measure = 75.32

[157, 158], breast cancer detection [159], and malignant melanoma on skin images [160]. In 2040, 600 million people will have diabetes [161]. Almost every medical institute and the hospital is trying to implement practical tools efficient, and accurate techniques to improve the process of decision-making. A wide variety of intelligent health systems have been developed to improve community health and reduce healthcare costs, among others, to enhance the quality of life. Such healthcare systems entirely depend on machine learning and profound learning algorithms [162].

In the modern age, deep learning has advanced in artificial intelligence. These techniques are effectively used for analyzing data, including images, sounds, texts, videos, and the like. In a smart city, we process large amounts of time series data loaded from connected sensors. The advantage of deep learning is that it is very suitable for analyzing continuous data. Time series data is continuous data in a unique format. The recurrent neural network shows excellent expectations for this particular type of analysis. You can quickly create applications on the Deep Learning platform in the previous figure. These applications use sequence learning models to solve various problems such as water distribution optimization, leak detection, and minimization of energy requirements. It is essential to understand the long-term time correlation between several data channels. This shines the deep learning algorithm. Once you are ready to train a good motor, you can control the actuators that can move automatically.

Feasibility of results in implementation and computation: The feasibility of implementing a smart city system that utilizes artificial intelligence (AI), Internet of Things (IoT) and machine learning technologies depends on several factors, including the availability and reliability of data, the scalability of the system, the processing power and storage capacity required, the security and privacy implications of the technology, and the cost-effectiveness of the solution. From a computational point of view, the use of IoT devices and sensors to collect real-time data from various sources can generate a massive amount of data that requires powerful computing resources to process and analyze. Machine learning algorithms can be used to extract meaningful insights from this data, but they require significant computational power and storage resources to train and optimize the models. Some of these challenges are addressed in this research article but some are left for the future research work. The implementation of a smart city system has designed with scalability and flexibility in mind in this comprehensive smart city survey article by utilizing distributed database processing technology to handle large volumes of data and enable real-time analysis. Additionally, appropriate security and privacy measures have some challenges which can be tackled in future work so that peoples of the city the data and should be protected and prevent from unauthorized access.

Future recommendations for smart cities

Here are some potential recommendations for the future development and implementation of deep learning in smart cities:

- **Develop more robust and efficient deep learning algorithms:** Deep learning algorithms are critical to the success of smart cities. Therefore, there is a need for continued research and development of more robust and efficient deep learning algorithms that can handle large amounts of data and provide accurate predictions and insights [163].
- **Prioritize privacy and security:** As smart cities become more connected, there is a risk of personal information being exposed. Therefore, it is important to prioritize privacy and security in the development and implementation of deep learning in smart cities. This can be achieved by using secure data encryption and ensuring that data is only accessible to authorized personnel.
- **Collaborate with local governments and communities:** To ensure the success of deep learning in smart cities, it is important to involve local governments and communities in the development and implementation process. This can help to ensure that the technology is tailored to the specific needs and concerns of the local community.
- **Develop user-friendly interfaces:** Deep learning technology can be complex and difficult to understand for non-experts. Therefore, it is important to develop user-friendly interfaces that make it easy for city officials and residents to access and understand the data generated by deep learning algorithms [163].
- **Emphasize sustainability:** Deep learning technology can help to optimize resource allocation and reduce waste in smart cities. However, it is important to ensure that the technology is used in a way that emphasizes sustainability and reduces environmental impact. This can be achieved by using renewable energy sources and designing smart city infrastructure with energy efficiency in mind [164].
- **Consider the ethical implications:** Deep learning technology can have profound social and ethical implications. Therefore, it is important to consider the ethical implications of using deep learning in smart cities and ensure that the technology is used in a way that is fair and equitable for all residents. This can be achieved by promoting transparency and inclusivity in the development and implementation process [164].

Conclusion

In this article, we have presented a comprehensive review of smart cities and how the vision of IoT and machine learning has changed the conventional way of understanding things and devices. We emphasize using a data-centric approach to embedding intelligence in the smart city framework using the large-scale data generated by deployed sensors. Particularly, the article begins with an overview of smart city applications, then details about multiple smart city components and their basic design on a hardware level. Further, we concisely present data sets and data acquisition technology for smart cities with innovative principles in different deep learning models. Although many surveys on intelligent cities are already published, here we have presented a comprehensive review that includes IoT-based sensor deployment, communication protocols, and architectural framework that collectively transform a city into a smart city. This review paper will set a direction for investigators and experts to apply machine learning with data sciences and mobile network backgrounds that will lead to a better quality of life and will open new economic opportunities for the business industry.

The future scope is very encouraging and promising seeing the rapid growth in smart devices, sensors, artificial intelligence, and machine learning. For corporate sectors and investors, there are new opportunities for designing smart building architectures with innovative structures. The emerging 5G and 6G technologies will help deploy these smart buildings for the welfare of residents and have the potential to change the way we realize smart cities today.

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