Sustainable Development for Smart Cities: Challenges and Opportunities

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Abstract: The world is developing on an unprecedented scale. Over the next 20 years, the urban population of developing countries will double to 4 billion and the area of urbanized land will triple. Rapid growth has helped create new opportunities, butit has also created serious social, economic and environmental challenges. Urban and rural communities around the world are increasing the need to address these challenges and become more resilient to poverty and inequality, social exclusion, violence and vulnerability, climate change and disaster risk. Building sustainable communities (villages, cities, countries and societies asa whole) is essential to combating poverty and promoting shared prosperity. With majority of the world's population living in cities by 2050, society must build cities that can intelligently meet the needs of current and future generations. There are successful smart/sustainable city initiatives and others that have failed. This paper attempts to understand related concepts such assmart city and sustainable development and sustainability. This paper then analyse five examples of existing smart/sustainable cityinitiatives and apply the SMART criteria as a governance perspective to understand what makes these initiatives successful. Finally, this paper concludes by presenting important implications and opportunities for future research.

Keywords: Smart City, Sustainability, Sustainable Development, IoT, Artificial intelligence

I. INTRODUCTION

54% of the global population lives in urbanized areas and cities, and this figure has been estimated to get increased by 66% by the end of 2050, with another 2.5 billion people expected to be added to the urban population over the next 30 years. With this expected population growth comes the need to manage the environmental, social and economic sustainability of resources. Smart cities enable citizens and local government agencies to jointly launch initiatives and use intelligent technology to manage assets and resources in a growing urban environment.

IOT-based air pollution monitoring system is used to monitor air quality through a web server on the internet. An alarm is triggered when the air quality drops below a certainlevel, i.e., when there are enough harmful gases in the air such as CO2, smoke, alcohol, benzene, NH3, NOx. Smart wastemanagement using wireless sensor network (WSN) and IoT(Internet of Things) has been proposed as a smart waste management system. Trash cans are used by sensors and are networked together via WSN. The sensors used by Trash collect data at set intervals. When the threshold is reached, it makes a request to the GCA (garbage collector agent). Smart street lighting uses powerful edge computing nodes that integrate data streams from smart lighting, environmental monitoring, and video sensors. It worksat the edge, enabling city managers to create connecteddata hubs that enable a multitude of new applications. For example, edge nodes can power city-wide parkingapplications when used in conjunction with cameras, networkvideo recorders(NVRs),management systems[2].

For Internet of Things-based smart parking systems that use web/mobile applications to transmit open and occupied parking spaces and parking lot information There is an Internet ofThings device with sensors and microcontrollers in every parking lot. Users get real-time updates on the parking lots' availability so they can pick the best one. Smart water management systems employ a range of sensors. They can be simple wire-based water level sensors, purity sensors like TDSsensors, and turbidity sensors. The amount of water sold (for rainwater storage) and the amount of water purchased (at the time of water supply) are applied to the water bill. Since the quality of water resources must be maintained at all times, datafrom sensors using Arduino and ESP8266 are sent to an onlineserver for monitoring and historical record keeping. This is all implemented on the blockchain, and all transactions are controlled so that bills and data on the quality of the water supplied cannot be tampered with. Since it uses blockchain, it also introduces microtransactions to ensure payments are instant [3].

II. RELATED WORKS

A Literature survey has been done to ensure the sustainable smart cities using current technologies. It is discussed in the tables 2.1,2.2,2.3,2.4,2.5 respectively.

S.No	***Title***	***Techniques***	***Advantages***	***Limitations***
1	*Air quality monitoring system*	*Sensing gasesfrom the sensors MQ135, LM35. Converting analog data into digital data and present it in LCD.*	*1.Detecting wide varietyof gases*	*Accurate measure of contaminated gases cannot be found.*
2	*Air pollution monitoring using ZigBee based wireless sensor network*	*Sensing gasesfrom MQ7 &MQ2 and then the data is sent to OP-AMP, ARM processor via ADC and transmitted and received through Zigbeetool.*	*Continuous update of air quality change in percentage.*	*Accurately predicted values cannot be measured ina toxic environment*
3	*IoT based air quality monitoring using arduino*	*Arduino ATMEGA328, IOT, air quality sensor, proteus.*	*Detects wide varietyof gases andthe system is simple and small*	*Data analysis isnot done soit is not ableto monitor the air pollution.*
4	*IoT based air pollution/quality monitoring system*	*ESP8266, PM2. 5 Particulate Matter Sensor, MQ-135 Air Quality Sensor & BME 280 Barometric Pressure Sensor.*	*pollution level of aircan be monitored using computer or mobile phone.*	*System is complex and cost is high.*
5	*A smart air pollution monitoring system*	*The model was designed using an Arduino Uno microcontroller ,Wi-Fi module 8266, MQ135 Gas Sensor, lcd*	*It can deliver real-time measurements of air quality.*	*It is not ableto measure wide varietyof gases*

Table 2.1 Air quality monitoring system

S.No	Title	Techniques	Advantages	Limitations
1	smart street lighting system	Sunlight sensing, traffic sensing, brightness control and error reporting system	Helps to decrease wastage of electricity	1. The implementation of an error reporting system to the electricity subsection is a difficult task 2. The switching of the lightning system between a maximum and a minimum mode is difficult.
2	wireless smart street light system	Works on wireless function using SaaS	No external wiring is required and overheating is reduced	Latency is more
3	automatic street lightning using LDR	Sense the light using LDR	Electricity is saved	Sensitive to ambient light
4	IoT based smart lightning system	LDR sensor and ESP8266 for IoT	Automatic switching on and off of lights	Sensitive to ambient light
5	ALG smart street and security light	Embedded Wi-Fi, IP camera and photo sensor, Polycarbonate housing and cooling engine	Smart parking, smart monitoring etc..,	Installation cost is more

Table 2.2 Smart Street lighting system

S.No	*Title*	*Techniques*	*Advantages*	*Limitations*
1	*smart parking management in smart cities*	*Parking is done by prebooking of available slots using an android application using IOT and parking detectors*	*Easy parking and easy online payment using online payment.*	*Expensive construction and installation*
2	*Smart car parking*	*IR sensor, Arduino, app*	*Shorter waiting time and Guides to the nearest available parking slot.*	*Requires regular maintenance and frequent system breakdown*
3	*Intelligent parking system*	*Arduino Nano, Two ultrasonic HC-SR04 sensors, RF Card Reader, Keypad, LCD.*	*Guides to the nearest available parking slot.*	*Not recommended high peak hour volume facilities*
4	*smart car parking using cayenne*	*Using Cayenne IOT and Arduino IDE*	*Reduced pollution and reduced traffic*	*Expensive construction and installation*
5	*automated car parking system*	*Implementation in μC/OS real time kernel*	*Useful for dynamic slot management*	*Lift mechanism needs Human assistance and priority is not given.*

Table 2.3 Smart parking system

S.No	*Title*	*Techniques*	*Advantages*	*Limitations*
1	*smart solid waste management*	*ultrasonic sensor temperature sensor gps module ESP 8266, Arduino Uno*	*It will stop overflow of dustbins*	*Segregation of waste is difficult and require more time.*
2	*smart garbage monitoring and management system*	*Waste management using Wi-Fi modem gps module Arduino IDE*	*It optimizes waste collection routes and schedules based on real time and historical data*	*Although it is easy to use, it difficult to install in the individual trashcan.*
3	*smart municipal waste collection management*	*Sensor based static waste collection garbage bins*	*Easy collection and minimal time*	*When the bin is actually just halfway full, sensors may report that it is full.*
4	*smart enterprise grade waste management*	*Pilot first approach using wsn*	*Increase service efficiency and optimise service cost.*	*Need frequent human support.*

Table 2.4 Smart waste management system

S.No	*Title*	*Techniques*	*Advantages*	*Disadvantages*
1	*smart rain water harvesting system (SRWHS) using IoT enabled smart kit for better tracking and management*	*Big data and bigdata analysis, smart kit and IoT*	*Enhance efficiency of water systems*	*Analysis could be incorrect sometimes due to different water PH levels*
2	*IoT based smart rain water harvesting*	*Layered Architecture using Wi-Fi and IoT smart sensors*	*Easy fault finding and easy monitoring of water flow*	*Implementation cost is more*
3	*sustainable rain water harvesting*	*Dynamic water supply sensor*	*Smart management of rain water and reduces wastage of water*	*Replacement of sensor becomes difficult if it is fault*
4	*intelligent stand-alone solar pv-enabled rainwater harvester and power generator*	*Automatic functioning of RWH using IoT with Solar power*	*Automatic and stand-alone system*	*Improper functioning during rainy season*
5	*sensor based rain water harvesting*	*Uses rain sensor to predict rain and uses PH sensor to check the quality of water stored in water table*	*Smart management of rain water and reduces wastage of water*	*Replacement of sensor becomes difficult if it is fault and rain sensors are unpredictable*

Table 2.5 Smart waste management system

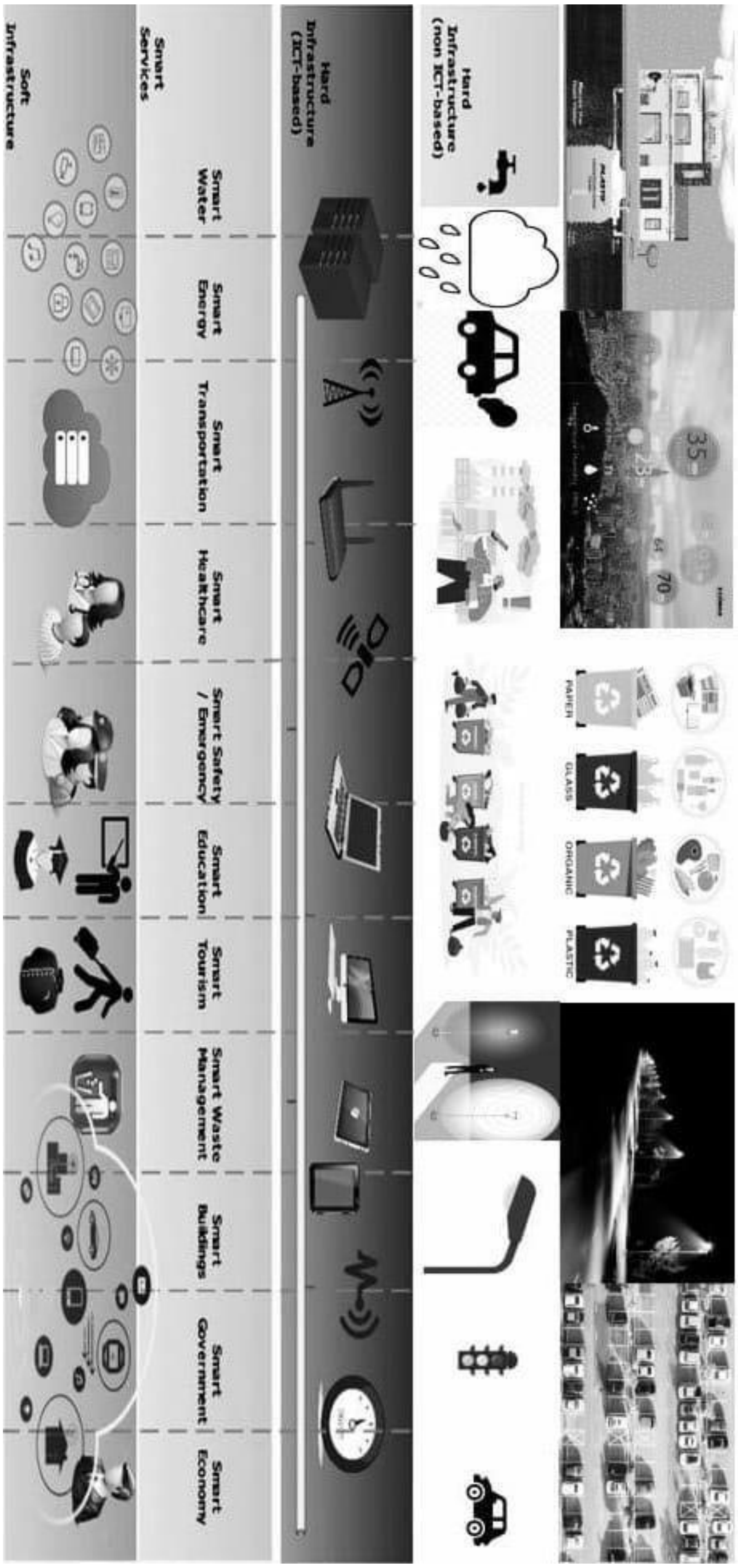

Figure 3.1 framework for sustainable smart cities

IoT based air pollution detection system

Federal Standards Act (FRM) or Federal Equivalent Act (FEM) monitors, which represent the scientific norm for air quality monitoring, are categorised as government-standard airquality monitors. This instrument is often used to help with decision-making, the formulation of policies, and the assessment of conformity with local, state, and federal regulatory criteria [4]. It has strict standards for measurement performance.

The biggest issue facing the industrialised world, or all industrialised nations, is air pollution. Particularly in urban regions of developing nations, where industrialization and an increase in the number of automobiles are producing various gaseous pollutants, health issues are escalating quickly. Pollution can cause minor allergic reactions like throat, eye, andnose irritation as well as significant issues like bronchitis, heartdisease, pneumonia, and an aggravation of asthma. According to studies, air pollution causes between 50,000 and 100,000 premature deaths annually in the United States alone. Their numbers can reach up to 300,000 within the EU, and they exceed 3,000,000 globally [5]. When the air quality falls belowa predetermined level, an IOT-based air pollution monitoring system uses the Internet to monitor air quality through a web server and sets off alarms. H. When the air is sufficiently polluted with toxic gases as CO2, smoking, alcohol, benzene, NH3, LPG, and NOx. The air quality will be shown on an LCDand on a website so that it can be easily checked. LPG sensor, which is mostly utilised in the home, is also added. The systemwill show the humidity and temperature. The device may be deployed wherever that there are gases, and it sends out a warning message when it goes above the threshold limit [6].

The following guidelines can be followed to improve Smart Airmonitoring system

- Users can examine the air quality statistics in their city using the FRESHAIR air quality app, which obtains accurate measurements of metrics like AQI and displaysthe users' exposure to pollution.
- It provides advice on how to handle circumstances wherethere is high air pollution as well as forecasted statistics onair pollution.
- Users can compare their city with other cities and receivealerts when the Air Quality Index changes.
- The FRESHAIR app has a simple user interface.
- To display pollution levels based on the user's presentlocation, it ought to integrate a map.
- Users of the FRESHAIR app should be able to look upother cities and obtain pollution information as well.
- It has a map facility to identify the polluted hotspot of thearea.
- Also, it shows a graphical representation of 1 week datarecorded.
- The FRESHAIR app provides advice on how to deal witha dirty atmosphere, such as what kind of mask to use, etc.

For sustainability, some features are added in air qualitymonitoring system like better urban infrastructure planning,Optimize city health by smart city air monitoring, Pollution source detection. Real-time Air Quality monitoring makes the city administrators to implement definite actions totackle the pollution and safeguard the residents' health andsafety. Some major responsibilities of administrators are tomake sure that people who are prone to polluted air have asafe breathing place. Also, identification of hotspots identification allows citizens to make decisions for selecting residential place. Polludrones network can help air polluted hotspot identification in the city.Data analysis and visualization software can authorities id entify high-traffic and highly polluted areas. Such data andinformation can help city planning boards make appropriate decisions. It is therefore an important tool for checking and making informed decisions about building schools, hospitals, bridges, etc. based on air pollution levels. City authorities face multiple challenges to ensure safe breathing conditions for citizens. Multiple Oizom monitors can be used to place air quality monitors throughout the city. Secondary data further facilitates pollutant distribution studies and enables legislators to punish polluters. The availability of translocal data monitoring allows air pollution authorities to take corrective action in real time.

AI enabled smart waste management system

Landfilling, composting and incineration havebeen the main methods used for decades and given their impacton ecosystems, are discussed in detail in the current chapter. explained. Proper handling of solid waste is necessary and supervision of the entire process from waste storage to water disposal is necessary [7].

Smart trash management focuses on employing sensors, sophisticated monitoring systems, and mobile applications to address waste management issues. The first intelligent waste management approach to improve the effectiveness of waste collection is the use of sensors. When the trash cans are full or nearly full, sensors can determine whether they are full and continuously update the disposal services to know when to empty them. These tools support the creation of intelligent driver schedules and the optimization of the optimal routes in fully filled containers. As jobs are derived, container selection reduces the demand for garbage collectors [8]. In the event of unwelcome situations like a rapid temperature rise or the displacement of a container by a GPS function, it is also capable of alerting trash disposal companies or municipalities. Real- time municipal insights and data intelligence are provided by the use of IoT to address waste management issues. Historical data is used to pinpoint specific vessel filling patterns, which are then adjusted over time. Other solutions include, mobile applications, used to meet typical smart waste system challenges such as drivers who will be working in the field [9].

The following guidelines can be followed to improve smart waste management system

- The waste management app named SMARTWASTE app permits users to monitor and track waste pickups and a lot more.
- This app is not only useful for the users and waste management organizations to ease their waste management business.
- Also, SMARTWASTE app allows the users to locate the routes of types of waste, embracing residential, recycling, or commercial. It will automate the processand speed up every weighbridge process, such as driver details, weighing of vehicle, truck number, validate previous data at the distinct checkpoints, and more.
- SMARTWASTE app aims to attain process efficiencyand get real-time data.
- It eases waste management operations with efficient waste storage manifesting, time tracking, and reporting to ensure complete compliance with global waste management regulations. Also, it helps meet various jobs, like waste collection, treatment, and

disposal of the waste material that may affect theenvironment's safety or human health.

- Also, it incorporates QR code inventory tracking modules that help keep every asset data in a single centralized asset management solution exhibited on acomplete asset tracking dashboard.

For sustainability, a Waste Management Billing section is developed for the complete operation, targeting electronic billing platforms development that backs online statements, payments, promotions, bulk mail discounts, invoices, and priceconfigurations. Also, it helps with robust billing options, rapiddata entry, and general accounting. A custom Waste-to-Energysection targeting monitoring, tracking, and automating every phase of the waste-to-energy conversion process is developed for transporting, sorting, and saving them to thermal, mechanical, and biochemical conversions. Besides, such app allows complete visibility and control over waste processing operations, allowing you to track the entire energy recovery process effectively. The Landfill/Transfer-Station Managementsection helps run ticketing, booking, yard, and scale house management in a centralized platform for outbound material planning, recording, and improved real-time inventory management and reporting.

IoT based rainwater capturing in smart cities (IoT)

There are two traditional techniques for rainwater harvesting. Storage of rainwater at surface for future use. Accumulation in groundwater [10].

In smart tanks, many sensors are employed. From wire-based water level sensors to more sophisticated purity sensors like TDS and turbidity sensors, we can handle anything. The water bill includes both the water sold (from rainwater collecting) andthe water purchased (when filling the tank) [11]. The data fromthe sensors is supplied to an online server with Arduino and ESP8266 for monitoring and historical recording because wateris a resource whose quality must always be maintained. Everything is done via the blockchain, and all transactions are monitored to prevent tampering with invoices and information on the quality of the water provided. It also introduces microtransactions because it uses blockchain.sopayments are instant [12].

The following guidelines can be followed to improve sustainable rainwater harvesting

- The app named RAINDROP app first identifies aproper location (rooftop, ground area, or both).
- RAINDROP app allows users to learn about local weather conditions and calculate the amount of rainwater that can be harvested at their location.
- Users must enter the roof area and specific ground level into the app.
- The setup of rainwater harvesting (manual work and hardware) done by PWD workers is documented and uploaded in the RAINDROP app.
- It collaborates with the respective weather station for that area. This is used to estimate the amount of rainwater the users can harvest.
- Users also need to feed the approximate daily water needs of their household.
- The RAINDROP app then recommends the amount ofstorage space needed.
- In addition, RAINDROP app also offers videos of lectures that provide lessons on how to reuse capturedrainwater, estimate project costs, and avoid common mistakes by users.

Ensure that the particular point of the water table level is greater than the daily water needs. The stainless-steel probes are installed at the specific point of the water table for this purpose. If there is nil or very little rainfall at a particular period, we can use a dynamic water supplysensor to provide the water accordingly for householdneeds. The rain prediction is done using machine learning and rain sensors. The quality of the water in the stored water table is monitored frequently by using a PH sensor to check if any drainage water is mixed with it. Finally, thestainless-steel probe sensor, dynamic water supply sensor, rain sensor, and PH sensor are connected via the Cayenne IoT platform and displayed via the app. An indicator is provided such that if there are any performance issues withany of the sensors, it will be indicated in the app. Unless the sensors are down completely, the rainwater harvesting system is sustainable.

IoT based smart parking system

Traditional parking systems include mosthomes, offices and recreation centres. Create separate parkingspaces for smooth entry and exit, improve organization andreduce traffic. Lighting is the only energy required, and less energy is required [13].

Problems such as traffic jams, limited parking and traffic safety will be solved by IoT. Here IoT-based cloud-integrated intelligent parking system is introduced [14]. The proposed smart parking system consists of an on-site deployment of IoT modules used to monitor and notify the availability of individual parking spaces. A mobile application is also provided that allows end-users to check parking space availability and book parking spaces accordingly. It also provides a general view of system architecture. Finally, we describe how the system works in the form of use cases that prove the correctness of the proposed model [15].

The following guidelines can be followed to improve smart parking system

•The app named SMARTPARK app includes a variety of features to help drivers find parking spaces, as well as detailed live information on opening hours andavailability, fees, directions and distances.

• All the Users in the SMARTPARK can see the prices of thousands of parking options on a map and compare them to choose the cheapest and closest.

• SMARTPARK app allows consumers to reserve and payfor seats in advance, saving time. There are live maps of street parking available in some selected cities. The timer function isuseful for overpaying and getting tickets. Turn-by-turndirections help drivers quickly find the property they want.

• In the simplest case, directions to available parking lots and price information such as parking times and fees are displayed. You can also filter by parking type, such as Disabled, Waiting Time, Pay & Display.

- It is also possible to install a payment function that allows youto pay with a smartphone without worrying about coins orcards at the payment machine. Another bonus of paying byphone is the remote charge feature. With this feature, the RAINDROP app can send an alert that paid parking is running out and prompt the driver to return to the car, or use theremote charge feature to extend parking time.
- The payment feature also saves current and previous parking transactions. This means drivers have instant access to previous parking transactions and bills.

Additional features can be added to make the system sustainable. With this app, consumers can save upto 50% on their travel costs, so users looking for big discounts will prefer this solution if they want to prepay for their seats. The platform provides access to thousands of valets, garages and properties nationwide. Business personwho travels a lot for work can update their profile to split the bills of parking into multiple accounts. Even though advance payment must be done for reservation of spots, there is no ad within the app. The platform notifies the user about it once parking time is running out. Premium account users can see spots available in real-time and have advance search features. If a driver could not find a spot in desired area, they can contactapp support to include the respective place to the platform, or drivers can simply add it by uploading a picture of the cark park design.

IoT *integrated AI enabled intelligent street light system*

Traditional street lighting operates on standard power grids thatgenerate energy from non-renewable resources. They arecarefully planned and connected in a series of structures. Traditional street lights had to be connected to the mains and powered by high voltage AC power lines [16].

One of the most often used pieces of civic infrastructure is street lighting. For the purpose of creating datagathering interfaces, sensors and street lights can be combined.Smart cities depend on the analysis of enormous volumes of data. The system for creating, deploying, and managing smart street lighting is suggested in this study as being extremely effective. Virtual deployments are made possible by container-based system management's quick deployment and high scalability features. Additionally, NoSQL and in-memory databases are integrated into the database design to achieve flexible data management. This study develops an asymmetric key and SSH encrypted tunnel for data transport. Additionally,use the token to run a sanity check after all services have been linked. As a result, the system assists in meeting the needs of smart cities for data throughput, low latency, setup, and realisation. High safety and efficiency are its defining traits. Inorder to facilitate massive data processing for smart cities, it also offers flexible data storage and management services [17].In terms of the experiment, this study develops a street lightingsimulation system using an edge computing device (composedof microcontrollers, sensors, and IP cameras) and street lightingfeatures. The suggested system allows for live image streaming,real-time environmental data collection, and historical data inquiries via an API. The viability of setting up all edge computing devices on servers using container-based virtualization and running numerous container-based services simultaneously on the edge computing devices is examined in this study. This system is quite valuable commercially [18].

The following guidelines can be followed to improve smart street lighting system

- The app named INTELLILIGHT app collaborates andcombines all the street lights virtually in the cloud premise in the form of nodes
  - First of all, the conventional street lights are replaced with low-powered LED lights and a high-resolution camera is placed for every 20 street lights which are connected altogether.
  - The camera captures the person or any moving objectand sends an alert to the system. And within seconds, the 20 connected nodes will glow. Simultaneous alertswill be given to respective connected nodes so that they will glow light as the object crosses them. This isalso ensured by the respective camera placed in the current connected nodes.
  - This makes the area a theft free zone as an additional benefit from the system, because there is an alertsystem placed in every 20 connected nodes and the subsystem is trained by machine learning algorithm sothat if the person or object seems odd, the subsystem will send an alert to the officials.
  - Also, if a new street light is to be installed in that area, then the user can request for the creation of a new node in the INTELLILIGHT app which gets notified to theofficials.
  - Similarly, if a street light gets to be updated to a higherlevel or to be dismantled completely, then the user canrequest for the node to be updated/deleted in the INTELLILIGHT
  - The INTELLILIGHT app has a map facility to accessthe location from where the node request has come from.
  - An integrated barcode is placed on every street light so that the user can scan the barcode and send the noderequest directly.

  As mentioned above, 20 street lights are connected as nodes inthe app. To make the system sustainable, we can divide the power of the connected nodes into two. The power can be generated using the waste heat generated from the led lights using thermos electric generators. The first half of the power isfed into the respective camera fixed on the own node. The second half of power is cumulatively collected and can be usedfor other light systems like traffic signals, charging ports etc.

V. **CONCLUSION AND FUTURE WORKS**

The scope of the document aimed at designing, understanding,and promoting environmentally sustainable and socially resilient smart cities and communities. This documentationgives an overview of sustainable cities and community development using various kinds of CS technologies [19].

The new approach proposed with respect to smart rainwater harvesting is the stainless-steel probe sensor, dynamic water supply sensor, rain sensor, and PH sensor that are connected viathe Cayenne IoT platform and displayed via the app. An indicator is provided such that if there are any performance issues with any of the sensors, it will be indicated in the app. Unless the sensors are down completely, the smart rainwater harvesting system is sustainable. The new approach proposed with respect to air quality monitoring system is to optimize cityhealth through smart city air monitoring, better urban infrastructure planning, and pollution source detection. The new approach proposed with respect to the Smart Street lightingsystem is that the power can be generated using the waste heat generated from the led lights using thermos electric generators.The first half of the power is fed into the respective camera fixed on the own node. The second half of power is cumulatively collected and can be used for other light systems like traffic signals, charging ports etc. The new approach proposed with respect to the Smart parking system is thatadditional features can be added, like making the system premium and reserving some seats for premium users so that slots are readily available and for premium users. Also, using maps, the user can navigate through different parking areas andselect the cheaper and better parking area. For the smart waste management system, different sections like the waste to energysection, waste management billing section, and landfill/transfersections are incorporated to make it sustainable [20].

For future works, the smart rainwater harvesting can be completely automated and abstracted such that only the required information will be sent to the users. Although the userhas admin access, the system will take care of the rainwater harvesting to be sustainable. For air pollution monitoring system, extra features can be added, like taking care of patientswith respiratory or airborne diseases. The app can be fed with the user's health details and train it using machine learning suchthat the app takes extra care and alerts the user at the particularthreshold level. For smart street lighting system, the app can collaborate with network companies to provide an extended service like Wi-Fi and other facilities. For the smart parking system, additional features like water wash, car repair services,tank fill services can be done on the user's wish, which can be fed into the app (for premium users). Future work for waste management system can be done by incorporating reduce reuserecycle technology with Artificial intelligence techniques in theapp by creating RRR subsystem. The waste content details which is first fed into the app. The app then segregates them andsends them to the RRR subsystem based on the type. And in that subsystem the waste can be processed further.

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