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IoT based smart garbage system for waste management and route optimization

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***Abstract*— This report primarily deals with finding the best practices and reliable solutions towards efficient smart garbage management practices and efficient route optimization of garbage trucks using technological applications. As per the set-out aim of the study different key considerations on methodology has been carried out following the relevance of the study and those have been played a critical role in formulating an effective understanding of the cost-effectiveness of the entire garbage management functions that could contribute socially and economically within the region. Most importantly, the two parameters such as shortening the distance travel of garbed trucks and time undertook to collect the garbage via route optimization and smart sensor system which could be controlled via a centralized command from the respective authorities. The literature survey has provided deep insight into the emerging technology application based on IoT that is crucial for maintaining garbage within the smart cities and around the communities effectively. It has been evidenced from the study that this implemented system via cost and distance matrix is highly cost-effective and this could facilitate the ensure Smart garbage management system resulting in harnessing environmental sustainability by having a clean and hygienic social environment.**

Keywords—Internet of Things, Smart Garbage, Waste Segregation,Route optimization

I. INTRODUCTION

The emergence of unprecedented environmental challenges and climate change has irreversibly impacted the change in policies and structures across different continents to foster technology-driven solutions for effective waste management practices. IoT based applications have been one of the predominant technologies that could be utilized for efficient waste management and route optimization. The emergence of Smart cities requires proper waste management solutions that have encouraged to implementation of such initiatives to identify areas and improvement of the existing waste management system (IOT5.net, 2022). A proper Well-designed system will help in monitoring the system within a community making work easier for the collection of trash. A sustainable system of disposing of waste will help in minimizing the risk of both human and animal health and preserving biodiversity. The route optimization for the system involves modules that are set up at various locations. IT works on an algorithm where inputs are being altered already in the system the path synchronization is given through output after evaluation of the process of the algorithm. IoT can provide a sustainable platform for accessing smart garbage management (Mishra et.al. 2019). The involvement of sensors and microcontrollers allows effective monitoring with the help of various GUI. IoT promises potential global change with its diverse network procedures and imminent connectivity. It assists in the planning of waste truck routes and creating criteria of factors that are needed to be considered such as environmental, economic and social factors. IoT based garbage management system shortened the fuel consumption cost used of garbage trucks and reduction of work amount. IoT devices send signals to the interface to detect the level of garbage inboxes and transmit such data to the application for further decision making (Erçin et.al. 2021). Therefore, developing one of the innovative systems for waste management and route optimization could contribute to sustainable environmental regulations maintenance along with providing a hygienic and risk-free health environment for the individuals.

A. Brief Current Scenario

Today the big cities throughout the world face some issues at the time of managing the city's waste effectively without making the city unclean. Nowadays waste management system includes numerous workforce who are appointed to attend dumpster conducted regularly. It leads to an unsustainable environment for the people and their well-being and has a detrimental impact on people health. In that regard, the fundamental objective of the study would provide a sustainable environment which is clean and neat communities and there would be smart dustbins that can be placed within the communities having a cost-effective embedded device for efficient tracking of the level of garbage in the bins. After reaching the higher level of threshold a message would be generated via GSM to the concerned authorities to take the garbed way within a stipulated deadline to ensure cost-effectiveness and higher efficiency would be achieved using efficient route optimization of the garbage trucks within the communities

to ensure the overall higher rate of return from the investment within the project.

B. Motivation to perform project work

In the existing waste management, the government manage the waste by the deployment of waste bin and employ various pickup business for collecting waste. The existing process of waste management is a cost structure that charges a fixed fee which causes issues related to the environment and increase the discharge of waste since there is no such restriction on huge production of waste and also there are no such incentives for light producers. As producers of food waste do not have direct expenses in generating waste therefore it causes issues to minimize the waste efficiently. To deal with such a problem volume rate system of disposal of garbage is needed to be implemented where RFID based systems of collecting garbage are presently being used. In RFID based system of collecting garbage, a collection bin consists of a communication module to communicate with a central server that has an RFID module assisting in reading data from RFID cards, automatic garbage entrance and scale function to measure the weight of waste. This bin communicates with a server and lack of communication between a machine with other collecting bins leads to overload of server. Also, in terms of delay, it is uncured from a critical process of discharge of waste from RFIS based garbage bins. Moreover, garbage collection based on RFID has a lack of effective mobility since a fixed power supply leads to the inconvenience of the user (Varma et.al. 2020). For this issue in RFID based systems that exist an IoT based SGS is required that fits in the category of applied IoT to the external environment that has essential components for such application. Furthermore, applying optimization to route lead to the minimization of a route which has made receptive of management of waste top improves the operational role in other areas such as location facilities and delineating service boundaries.

C. Objectives

The primary aim of the study is to manage the waste through a smart garbage system based on IoT along with route optimization efficiently. In this regard, the solutions that this system would offer are smart dustbin having different sensors that are connected via cloud system and providing a cost-effective pathway for the garbage collections via trucks.

The objectives of the study are-

- To understand how IoT based SGS assist in creating sustainable urban life.
- To analyze the application and model of IoT based SGS used in smart cities.
- To investigate how route optimization helps in the effective management of waste within the cities.

D. Target Specification

The fundamental goal of the project is to develop an innovative Smart Garbage System that would help in minimising the distance travel by the garbage truck and reducing the total time travel of the garbage vehicles. The fundamental aim is to develop a cost-effective and sustainable system that could help in generating the desired level of hygienic and clean environment contributing to the overall health and wellbeing of the individuals within different communities.

II. LITERATURE REVIEW

This chapter will represent the critical review of the research and previous studies that are conducted in the scope of this specific topic to develop a wider range of secondary information and maintain the researcher understanding of the researcher as well as the reader.

Internet of Things is the concept that surrounds the objects that are connected by the wired and wireless network in absence of user intervention. In the aspects of IoT, the objects communicate and exchange information to offer advanced intelligent services for users. On the characteristics and merits of IoT services, waste management has also been considered to be a significant issue as a major field of IoT application. An indiscriminate along with illegal waste discharge, an absence of disposal of waste and management system, inefficient policies of waste management have caused serious problems related to environment and have incurred the approx. cost for disposal waste. To handle such issues several researchers have conducted their research studies on waste management platforms and systems.

Based on the study of Navghane et.al., 2016, it has been evident that to implement a smart garbage bin the field of IoT find its grip where the bin is designed with a weight sensor, IR sensor and module of Wi-Fi to transmit data. These dustbins are interfaced with a microcontroller-based system that includes a system with IR wireless and a central system showing the present status of garbage on a web browser by Wi-Fi. Thus, the status will be updated on the web page. This system assures the dustbin cleaning soon when the level of garbage reaches the level of maximum. In case the dustbin is not cleaned at a particular time, then the record is sent to a high level of authority taking appropriate action against the contractor responsible. This system also assists to monitor the reports which are fake and thus can minimize corruption the throughout management system. This leads to the reduction in an overall number of trips of vehicle collecting garbage and thus reduction of throughout expenditure align with a collection of garbage. It ultimately aids in keeping

cleanliness in society. Thus, a system of smart garbage management assists in making the collection of the garbage more efficiently. This system is vulnerable to plunder components in the system in various ways that need to be worked on.

On the study of Suryawanshi et.al., 2018 it has been evident that waste management is the primary issue which is faced by the world irrespective of a developed and developing region. The actual issue in managing the waste includes the garbage bin at a public place that gets overflowed before the commencement of the next process of cleaning. This leads to several hazards like bad odor which is the root cause for spreading numerous diseases. To avoid these hazards effect and maintain public cleanliness along health that is mounted on smart garbage system. The actual aim of the work is to develop an alert system of smart intelligent garbage for effective garbage management. This alert system is used to clear the garbage by providing an alert signal to a municipal web server for instant clean of a dustbin with effective verification depending on the level of filling of garbage. This process is assisted by an ultrasonic sensor that is interfaced with Arduino UNO to check the filling level of garbage in a dustbin and send alerts to the municipal web server once the filling of garbage is done. After the dustbin is cleaned, the driver confirms that the task of garbage is empty with the help of an RFID tag. It is the computing technology that is used to verify the process and also improves the alert system of smart garbage through offering automatic analyzing dustbin filled with garbage and therefore sending status of cleaning up to the server affirming that the work is performed. The overall process is conducted by an embedded module integrated with RFID and the facilitation of IoT. The actual time status of the way waste collection is conducted could be monitored along with following up through municipal authority that helps this system. Moreover, the necessary alternative measures could be adapted. An android application is developed and is linked with a web server for the alert intimation from micro-controller to urban office and conduct effective monitoring of the process of cleaning, performed by workers and thus reduces the manual monitoring process and verification. The notification is sent to the Android application by utilizing a Wi-Fi module.

In the study of Hong et.al. 2014, it has been evident that IoT using RFID technology was limited to tracking the object and extracting information to particular objects. The present IoT conducts sensing, actuating, gathering data, storing and performing the process by connecting virtual devices to the Internet. In food waste management exist local government manages food waste through the deployment of bins that collects food waste and employ numerous pickup businesses for collecting food waste. The current method of food waste management leads to environmental-related problems and enhances waste discharges as there are no such restrictions on heavy manufacturers of food waste and no incentives for light producers. As food waste producers do not have a direct impact of expense to generate waste, which is difficult to reduce the amount of waste. Also, a lower level of reliability of statistics on food waste has led to difficulty in adjusting and monitoring the discharge amount as local government hires several pickup businesses for collecting waste and each of them utilizes various measuring methods. An adaptive user-oriented charge policy is utilized to influence residents in reducing food waste and web-based services are offered to acquire more efficiency in the disposal and process of collection. It has been surveyed that this proposed system with this charging policy leads to the reduction in food waste of about 33% and have expectation that the proposed system will thus enhance the efficiency of management of food waste. This smart garbage system needs more effective maintenance cost than the system that exists and thus is a tradeoff owing to the proposed system's structure being power-based. The key importance includes the way to enhance the life of the battery of smart garbage bins. To solve the issues, photovoltaic power generation is being considered. Additionally, a high level of intensity of plastic materials is also considered for durability against external effects and corrosion from humidity.

Based on the study of Zohari and Zulkefle, 2020 the smart garbage monitoring system includes preventing dustbin overflow which can cause environmental pollution and disease to the public. To keep away from all hazardous situations and keep up tidiness and well-being this system is about to mount on smart dustbin hardware. The primary aim of this dustbin is to innovate typical dustbin to effective waste management by providing a notification to authorities and cleaning of workers to gather garbage on time. The project utilizes an ultrasonic sensor that is interfaced with the WeMos Wi-Fi module to check the height of waste that is filled in the dustbin and sends an alarm to workers involved in waste management like Blynk application once the trash is prepared for collecting waste. DHT11 is a temperature sensor along with a moistness sensor that is additionally interfaced with the WeMos Wi-Fi module. WeMos will send data via the internet to provide notification to the authorities through the Internet of Things Platform. Moreover, the ultrasonic sensor is used to detect movement across the dustbin to provide commands while opening and closing the dustbin lit automatically. Also, the installation of a gas sensor on a dustbin is utilized to detect the smoke which can be the actual factor of fire burning. The proposed framework uses an ultrasonic sensor to put greater trash dimensions. The framework consists of an ARM microcontroller that controls the framework activity by everything that is associated with the database. This working framework will attempt in screening profundity and waste sorting. On a contrary, this system is so designed to minimize the effort of humans and build effective waste management through

utilizing the concept of application of the Internet of Things.

According to the study of Medvedev et.al., 2015 it has been evident that Intelligent Transportation System (ITS) allows innovative services within smart cities. Efficient collection of waste is considered to be the fundamental service for Smart cities. IoT can be applied both in ITS and smart cities that forms an advanced platform for the novel application. System of surveillance can be utilized as technologies that can assist for a higher degree of Quality of Service (QoS) in collecting waste. Particularly the components of IoT includes RFID, sensor, camera and actuator that are incorporated into ITS and surveillance system for efficient collection of waste. An advanced Decision Support System (DSS) assist in the efficient collection of waste in smart cities. The system includes a model for sharing data among truck drivers on actual time in terms of performing a collection of waste and dynamic route optimization. The system handles the case of ineffective collection of waste in an inaccessible area in the smart city. A surveillance camera is incorporated to capture the problematic area and offers evidence to the authorities. The system of collection of waste aims in providing higher QoS to the citizens of a smart city.

According to the study of Adam et.al., 2018 it has been evident that the system of smart waste garbage management system can be improved by connecting the system with a GPS that determine the bin location and send message to the near waste vehicle to empty the bin and utilizes Internet of Things to monitor and access bins from any location. A structure that utilizes three-part includes coordinate node, end device node and web server design. The coordinate node and end device mode are interconnected by radio transceiver, coordinate node connection depending on ZigBee protocol. Several sensors are utilized like level sensor, Gas sensor and load cell. This system will be beneficial in keeping dry and wet garbage in separate positions so that various processes of composting, recycling, and incineration implement various types of garbage. Through intimation of garbage-filled notification, the utilization of garbage collecting vehicles will be optimized and thus the environment remains clean and contributes towards society. Architecture that is based on Internet of Things (IoT) and is categorized into three modules includes a system of smart control sensing which includes Ultrasonic sensor, PIR sensor, servomotor, RFID reader, transceiver unit that consist of GSM, Wi-Fi and Smart display unit that consist of LCD, Database, monitor section. The proposed framework can be expensive and is inevitable to limit the waste accumulation within populated cities. A weight sensor is utilized to detect the waste amount but an accurate level of waste is not determined. The smart collection system depends on the Internet of Things sensing prototype that measures the level of waste in a container and sends data through the Internet to a server to stores and process data. Depending on the data process of optimization allows in creating effective collection routes and it is forwarded to workers and is executed in Geographic Information System simulation environment. The architecture of the Waste management system is divided into three parts that include smart bin, monitoring and control system and garbage truck part. The figure 1 Illustrates system architecture-

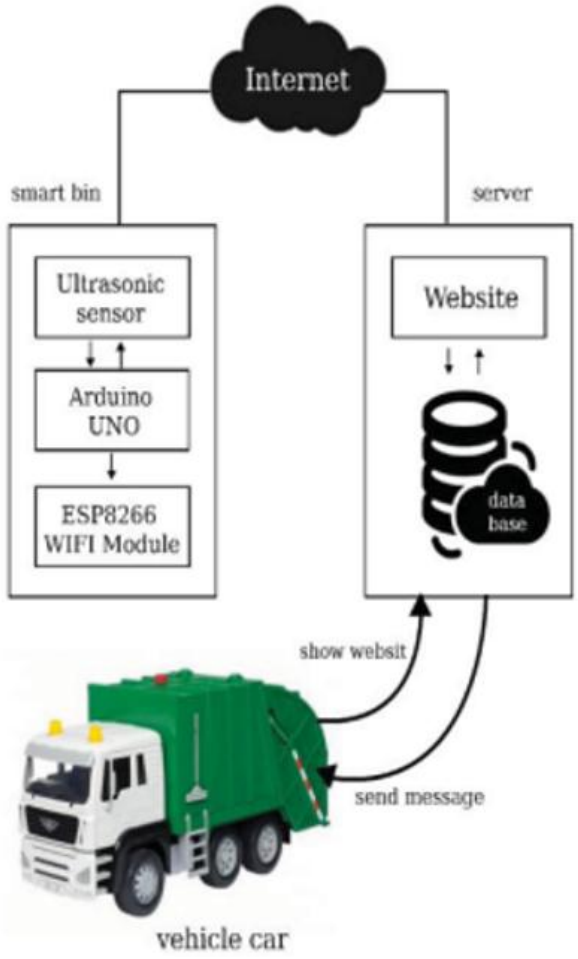

Fig. 1(System Architecture)

The data is read through using an ultrasonic sensor that analyzes the waste level in every container. The levels are divided into three categories that are empty, half and full. In case the container is full the message is sent to the vehicle car to the empty bin, a module of Wi-Fi is utilized to send data through Internet protocol TCP/IP to a web page, and data are stored in a database for further analysis to control the distribution of content in a specific location. The system was linked to Google Maps to analyze and display the location of the container on the map.

Based on the study of Pardini et. al., 2019, it has been evident that with the enhancement of the density in population and rural exodus to cities, urbanization is assumed to extreme proportion and presents urban issues

associated with the generation of waste. The enhancement of the generation of waste has been considered to be a significant challenge to large urban centers and represents a critical problem for countries with the accelerated growth of population in cities. IoT and cloud computing provides automation of possibility by a hyperphysical system which will change the way management of solid waste is conducted. Understanding the integration of various empowering technologies in the system provides improved insight into the meaning of every functionality in the context of IoT. The technologies play an effective role in solid waste management systems based on IoT. The activities are aligned with the beginning of the cycle by identifying every compartment. It is aligned with useful sensing and capacity to accurately the present condition of the level of service with effective communication and the ability to provide the minimum need necessary for effective functioning of the system. Additionally, an applied computation is included in breaking the information which meets the need of the user within a large amount of gathered data that is accessed by simple services and is easy to utilize until the semantic representation of the information through the object.

In the study of Mishra et al., 2019 it has been evident that waste management has become an immense concern in terms of present cities. Improper management of waste leads to unclean, unhealthy conditions within the city and thus spreads various diseases leading to improper logistic management and human resources. However, IoT has brought a revolution in the traditional way of developing smart cities in numerous fields. For proper management of waste and optimization of collection of waste and disposal system, it is required to avoid scenarios of an overflow of waste in the aspects of technology that enable smart cities. The waste bin is divided into 3 types which are biodegradable, non-biodegradable and metallic. Real-time monitoring of the level of garbage within the waste bin is periodically sent from every location to a centralized cloud platform. Whenever the level of garbage within the waste bin reaches a threshold, the vehicles collecting waste are routed as per decreasing percentage order of filled waste in dustbins of several areas. The primary objective is to save resources and strict constraints of the waste bin that has been overflowed.

A. Summarized Outcome

From numerous studies, it has been evident that the implementation of smart garbage bins in the field of IoT helps in minimizing the corruption in the overall management system leading to a reduction in the trip number of vehicles. The waste management system utilizing IoT has implemented waste management in real-time by using a smart dustbin to check the level of fulfilling dustbin to check whether it is fulfilling or not. Smart Garbage Bin can contribute not only to the reduction of food waste but also saves energy and thus enhances the efficiency of waste management. The software used in smart garbage monitoring systems along with safety features applications are capable to designed and constructed through the implementation of programming techniques depending on Arduino IDE and WIFI module. It has also been evident that concessionaires are accountable for a public collection that always meet the demand on time, changing the present system of collection depending on weekly schedules through methodology depending on the demand that is mapping the areas with most important needs.

III. METHODOLOGY

This chapter would provide a succinct understanding of the tools, techniques as well as approaches and strategies undertaken to carry out the research. With the help of desired tools and techniques of the study following mixed research, methods have been taken into consideration which would further emphasize the appropriateness and suitability of the system within different communities, localities and smart cities.

The major components of the smart dustbin would be having ARM CORTEX M4 1765, PIR sensor, load cell, GSM device and ultrasonic sensor system.

A. Providing path for the garbage collection via truck and data collection

First of all, this has been one of the significant aspects that would be decided based on the best cost-effectiveness and for this, the pathway would be provided based on the data received from each dustbin and level of prioritization would be provided based on the time left to fill the dustbin.

Secondly, the nearest algorithm has been used to understand the shortest path for the truck to travel and with the help of such a system, there would be a reduction of fuel and resources costs. This would essentially make the entire system more reliable due to the application of IoT.

Thirdly, there would be no need to monitor the individual sensors as the entire IoT system would be managed using a centralized system that is connected through cloud and internet technologies (Khandelwal et.al. 2019).

In this context, an approximately 2 Kilometer area of a community has been taken into consideration having a population of 30,000 and available resources are Solid waste trucks and garbage van three of each. Based on the collected data related to the cost of transportation, time consumed and distance, as well as a volume of the solid waste and capabilities of transporting volume of individual vehicles, have been undertaken.

Therefore, based on the available data set the distance matrix and cost matrix would be developed and thus the

reliable calculations related to the most cost-effective approaches towards waste collection and transportation could be generated successfully.

The network topology has been illustrated in Figure 2.

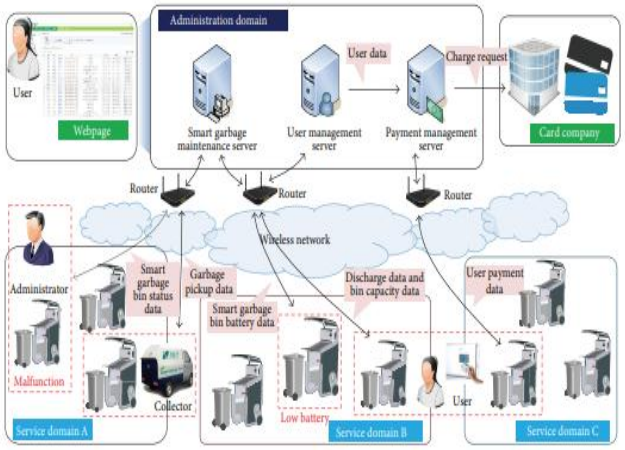

FIGURE 1: Overview of smart garbage system.

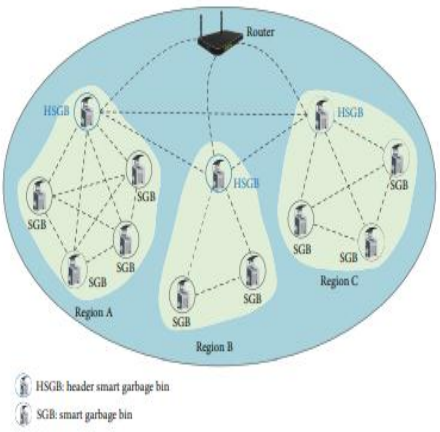

Figure 2 *(Network Topology)*

Source- *Insung and DaeBeom, (2014)*

IV. SUMMARY OF OUTCOME

This chapter has summarized the collected data set for the distance matrix and cost matrix and they have been illustrated as follows.

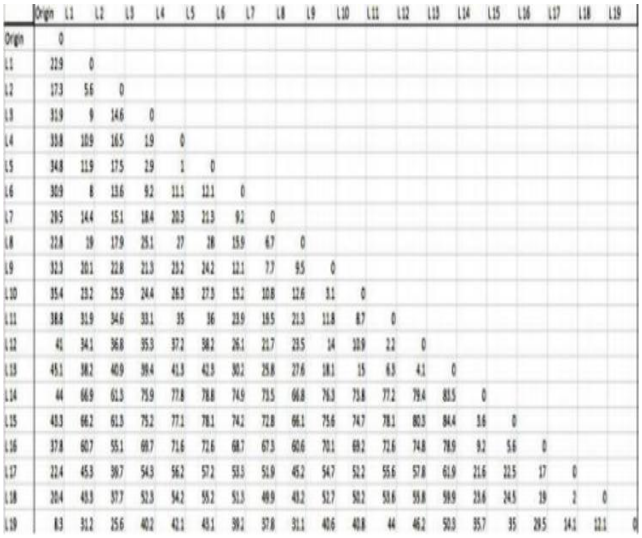

Fig 3 *(Distance Matrix)*

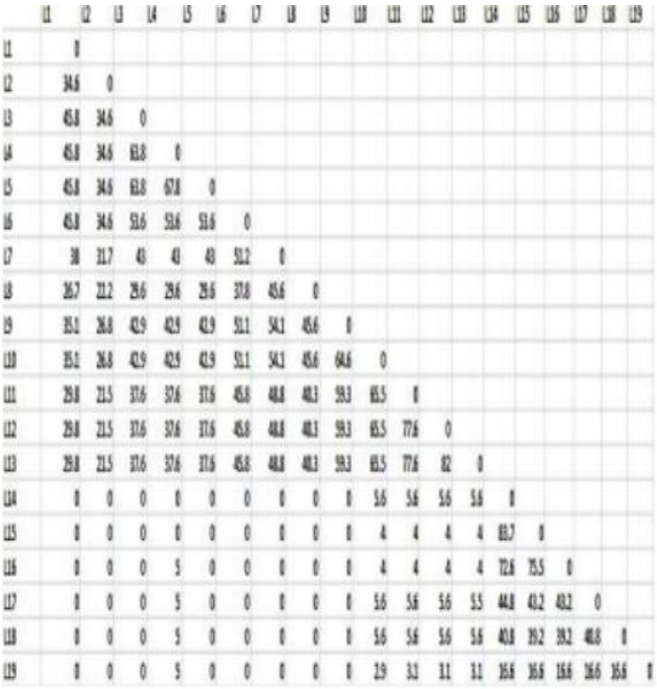

Fig 4 *(Cost Matrix)*

The above cost matrix would provide a succinct understanding of the total cost that would be required to travel from one path to another path via the garbage collection trucks.

A. Result analysis

a. Nearest neighbour

This has been obtained through the origin point where it adds the closest individual household to extend the entire trip and, in each step, it automatically adds different individuals to the points where the vehicle has been visited

last and accordingly it continues in such process until all of the individual households are visited effectively.

For better efficiencies, in calculations, the entire 21 points of the garbage collection route have been divided into two categories such as 14 plus 7 points for enhanced convenience.

Route 14 point-

Origin >3>1>2>4>5>6>7>8>9>10>11>12>13>14 origin

12.1+4.3+7+8.1+8.9+1.6+1.3+19.5+7.6+8.5+2.1+7.8+2.1+3.2+31.2=125.3 units

= 3.29 Kms

Thus, this would result in savings in distance travelled 0.9 kms and 13.4% savings from the present route.

Route 6 point-

Origin> 21>20>19>18>17>16>15>Origin

7.1+6.9+1.5+14.2+4.6+3.9+31=69.2 units=1.61 Kms

Thus, this would be saving the distance of travel by the garbage truck by 0.54 km which is essentially saving 8.1% from the current route.

b. Deviation from expected results and justification

It has been evidenced that the Smart Dustbin system and having a robust framework using IoT and cloud infrastructure with internet technologies has certainly evolved the process of waste management within the community and this, in turn, results in better cost savings on waste management practice and the level of expectation in term of efficiencies has been achieved. However, due to the fundamental aim of understanding and formulating a way that is cost-effective ensuring a clean environment could be regarded as the success parameters of the study.

V. SUMMARY OF WORK

Based on the available dataset the fundamental parameters of distance travelled is not the best alternatives as there are numerous system such as using RFID and cloud sensor in the smart bin has played an important role to collect the garbage on time in a cost-effective way. With the use of technology and from the findings it can be stated that this could be implemented on a large scale which would, in turn, provide a sustainable environment and provide pathways to ensure cost-effective garbage management practices in line with environmental sustainability.

A. Conclusion

This paper emphasizes proposing an IoT based smart garbage system to replace the existing garbage collection system based on RFID. To offer differentiation from passive collection bins and other types of systems of collecting garbage based on RFID the researcher has proposed different components which are required in a public environment and designed SGS based on the components. The primary system structure of SGB is a centralized structure where the information is gathered in every bin that is transferred to a server and also designed an HSGB to improve the efficiency of the battery of every SGB. Adaptive user-oriented charge policy is utilized in motivating residents to minimize the waste and web-based services are offered to acquire more efficiency in disposal and process of collection. Moreover, based on the proposed system utilizing SGB it has been evident that the energy efficiency of the proposed SGB shows 16% savings of energy that contributes towards the reduction of waste and also savings of energy. The proposed system and adaptive user-oriented charge policy leads to the reduction in waste of near about 33% and is expected that the proposed system will thus enhance the waste management efficiency. The POC testing of the iSmartWMS system has been demonstrated successfully where a solution of iSmartWMS is carried out effectively intended to functionalities. Because of limited data of test and lack of real-life waste material data, effective iSmartWMS PoC are unable to test and is difficult to judge the throughout the performance of iSmartWMS as a Smart waste management system. Moreover, encouraging outcomes confirmed that iSmartWMS can be effectively utilized for Smart waste management when implemented effectively. Also, utilizing route optimization is to build a useful route because of the constant change of essential parameters which determine the route of waste collection (Aithal, 2021). Moreover, the model of the waste collection consisting of route optimization has been implemented. The proposed model of route optimization suggests an optimal route to the system of collection of waste with variable, parameter and constraint of system build by creating relation among variables. This model is proposed for the primary use of the system in the area and is anticipated which improves in optimization of a route through utilizing AI and machine learning and therefore improves in the generated algorithm that can be made through gathering data regarding waste bin. As the data related to filling time of the bin with time, analysis of route will be enhanced through utilizing machine learning. A prepared model will be used in the first utilization of the system and then the route will be automatically built from historical data that uses techniques of machine learning and thus saves time. Depending on distance solely will not provide an effective solution as the system is based on many aspects from the distance travelled and expended fuel. This is evident through observation made in simulation and the shortest route is one with the most amount of solid waste that is

uncollected at trip end. It is seen that there is two cause why there is a chance of a decrease in cycle time. One is due to the route being shorter and next is the last pick-up point that is left unattended as the truck is full which means that when there is uncollected garbage, the cycle time is shorter. The concept of the effective route depends on the perspective is provided with priority. The collection process and disposal of solid waste is very complex even when they are considering the part of transportation.

B. Future Scope of Work

The proposed SGS needs more cost maintenance than that of an existing one and there is a tradeoff leading to the proposed system of a power structure based on battery. Based on improving results obtained through verification and validation of iSmartWMS PoC it is recommended to implement an effective iSmartWMS system. It has been recommended to integrate it with the available infrastructure of smart cities and validate against real-life waste generated data. While conducting laboratory test of iSmartWMS PoC some valuable suggestions are required like-

Web interface providing iSmartWMS PoC to access over the android phone for the easy and convenient process of authorized staff and thus provide more flexibility.

Apart from visual indication, the audio alarm must be provided regularly if any trash required immediate servicing.

Offer facility to integrate iSmartWMS system software with the smart city with the existing infrastructure of IT.

Facility to view bin of Smart trash that contains video footage to the users who are authorized.

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