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Automated Solid Waste Management System for Under Developing Cities (A case study for Karanjade Region)

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Abstract – *India's current population is approximately 1.4 billion and it is going to increase rapidly over the next few decades. Due to the ever-increasing population and urbanization, the volume of municipal solid waste (MSW) generation has also increased in the past few years. Improper municipal solid waste management possess a risk not only for human health but also to the environment. Hence, municipalities face a significant challenge for solid waste management. Karanjade is a newly developing area hence the Panvel municipal corporation is trying to make it a smart city and provide smart solutions to its residents. Therefore, traditional waste management systems are replaced with super technology automated waste collection systems. This case study focuses on the collection of solid waste at two parameters: the first part of collection is using an IoT system for an already developed region which also incorporates route optimization and the second part of collection is using a pneumatic waste collection system for newly developing region. The other significant advantage of this automated waste collection system is that the solid waste is segregated at the source of origin which lessens the burden of the laborers working at the transfer station.*

***Key Words*: Smart cities, Solid waste management, IoT system, Route optimization, Pneumatic waste collection system.**

1. INTRODUCTION

Solid waste is the undesirable or useless solid substances generated from human sports in residential, industrial, or commercial areas. In developing countries like India, the municipal solid waste generation has greatly accelerated due to increasing population, urbanization, thriving economy, the standard of living, careless attitude of citizens. According to the "Swachhata Sandesh Newsletter" by the MoHUA, as of January 2020, 147,613 metric tonnes (MT) of solid waste is generated consistent with day. Per capita waste generation in major Indian cities ranges from 0.2 Kg to 0.6 Kg. Hence municipalities are under tremendous pressure for providing effective and efficient waste management to the citizens. smart cities must provide smart solutions hence conventional waste collection systems are being replaced by modern automated waste collection systems. Automation systems are more efficient and productive, which in turn reduces the consumption of labor, resources, energy, time, and cost of operation. hence it shows supremacy over the conventional systems. Studies have shown that the generation of MSW has rapidly increased in the last decade as compared to its previous decade. In India only 23% of waste is undergoing treatment and the remaining 77% of waste is just dumped in landfills. Due to open dumping at such a humongous rate, India faces severe environmental and health hazards. Leachate generation from landfills causes air and water pollution which not only affects aquatic life but also the quality of vegetation. Since Karanjade, Panvel is a newly developing region, this case study intends to propose a study methodology for the management of solid waste using a combination of low-cost IoT technology and a Pneumatic Waste Collection System.

2. SITE DATA

Karanjade is situated in Panvel, Raigad District, Maharashtra. The entire region is divided into 6 sectors. Sectors 1, 2, 3 are situated near the newly constructing Navi Mumbai International Airport and it is underdeveloped as of now. Whereas sectors 4, 5, 6 forms the developed settlement. The population in Karanjade is approximately 4000.

2.1 SITE DETAILS

Table -1: Site Details

Location	Sectors 1-6, Karanjade, Panvel, Raigad District, Maharashtra.
Governing Authority	CIDCO
Area	2.38 square km
Distance from nearest railway station	Approximately 4 km from Panvel Railway Station

Fig. 1: Site Location

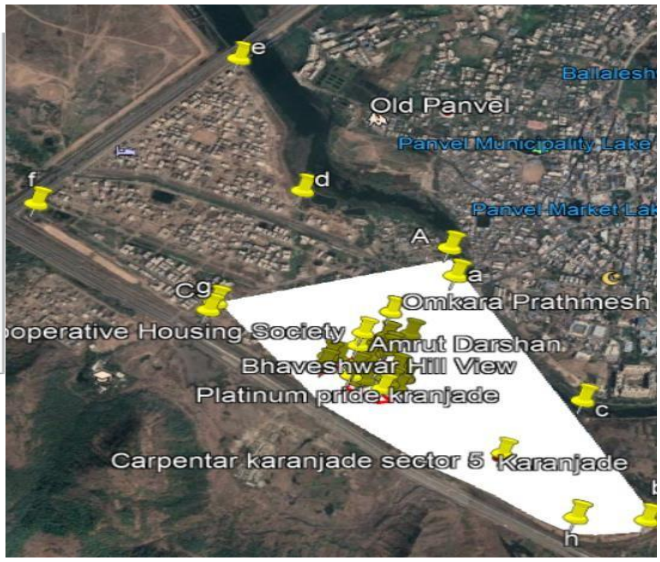

Fig. 2: Sector 4, 5, 6, Karanjade

3. METHODOLOGY

Waste collection, storage, and transport are important factors of any solid waste system, and coping with it effectively is a major challenge in cities. Open burning of unsegregated waste is one of the biggest concerns of all time.

Local bodies spend around Rs.500–1000 consistent with a tonne (which contributes up to 5 -40% of the annual budget) on SWM with 70% of this quantity spent on collection and 20% spent on transport.

The adoption of the computerized era of waste collection and transport infrastructure in India will create greater activity opportunities, enhance public health, environment which will indeed increase tourism.

3.1 IoT SYSTEM: For developed cities

The booming use of **IoT** along with smart devices and sensors can reduce unnecessary expenses because of operational incompetencies in trash collection processes.

Inspiration for this case study was generated from "Integrated Sensing Systems and Algorithms for Solid Waste Bin State Management Automation" [1] have already provided a sensing system and set of rules for a solid waste bin to automate the solid waste collection process.

Sector 4, 5, 6 which is a developed settlement is taken into consideration for the IoT system.

3.1.1. MECHANISM

This case study provides a hypothetical theory of monitoring of the dustbins from a remote place by considering two parameters:

1. Sensing the extent of waste-crammed in the dustbin
2. Sensing the weight of the waste crammed in the dustbin [2]

The sensors work on the principle of time of flight. The principle of time of flight indicates the amount of time taken by an ultrasonic pulse to transmit and receive its reflected echo between the sensors and the waste level. 3 sensors will be used per dustbin. Two sensors will be located at the best factor of the dustbin (80% of the level of the dustbin), these sensors will detect the level of waste accumulated in the dustbin with precision and are configurated with a PIC microcontroller. The other sensor is located at the lowest of the bin and is interfaced with a controller to feel the load of the solid waste gathered in the dustbin.

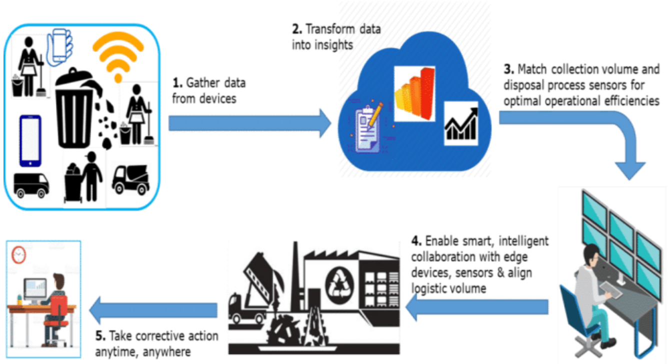

Fig 3: Process of IoT system

The controller receives signals from all 3 sensors. The Arduino unit which acts as a receiver decodes the encoded facts originating from the PIC microcontroller via an RF transmitter. RF transmitter sends the statistics to RF collector that is connected with Arduino Ethernet shield. The information received by the collector via Arduino is transferred to the internet service via the Ethernet shield.

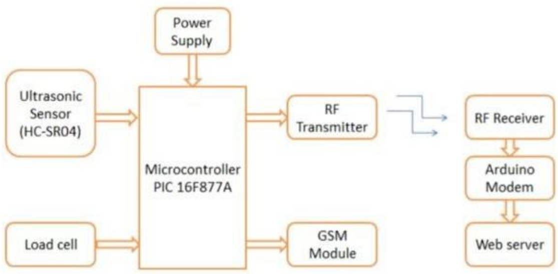

Fig. 4: Flow diagram of the system

The status of the height of garbage in the bin is detected via way of means of ultrasonic sensors and the weight of waste in the bin is diagnosed via way of means of the load cell sensor. The system is coded in such a way that a LED is displayed when the garbage reaches its maximum threshold and an encoded signal might be transferred with the aid of using the RF transmitter. Then Arduino modem connected with the Ethernet Shield receives the signal through the RF receiver. Due to the connection through the Ethernet Shield, the live status of bins can be seen on the webpage. The municipality can monitor this webpage 24/7 and can easily track the level and weight of the waste collected at a particular location. The municipality receives the alert message through the GSM module when the bin surpasses its limit and accordingly, they can dispatch a team to unload the waste from that particular location.

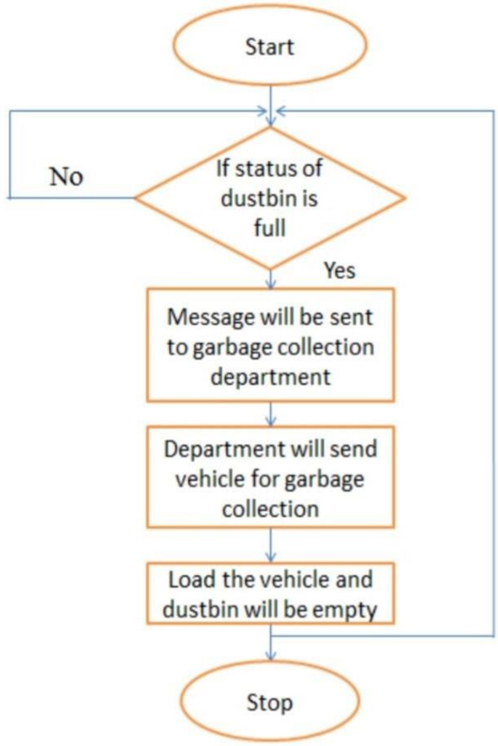

Fig. 5: Flowchart of the IoT system

Fig. 6: Municipalities gathering waste after receiving an alert from the GSM module

3.1.2 ROUTE OPTIMIZATION

Route optimization means determining the most cost- efficient route. In MSW, well-planned route optimization can decrease the hauling cost, which contributes to 85% of the total disposal expense [3]. Route optimization not only reduces the overall distance but also vehicle drive time to collect and transport municipal waste from container bins. For Our Project, we have selected sectors 4, 5, and 6. This route has 22 buildings. In this route, the total traveling distance for the collection of waste after route optimization is 1.3km. Approximately the proposed scheme may be capable of lessening greater than 35% of the total waste collection path length.

Fig. 7: Route optimization

Route optimization will give the added advantage of reduced noise pollution, traffic jams, etc which will, in turn, save resources

Fig. 8: Before vs after route optimization

3.2 PNEUMATIC WASTE COLLECTION SYSTEM: For newly developing cities.

A Pneumatic Waste Collection system is a total water and air tight system. It consists of a network of underground pipes through which a vacuum is created to transfer the waste to the transfer station.

Fig. 9: Pneumatic waste collection system setup at a residential complex.

The pneumatic waste collection system advocates segregation at the source of generation which helps in the further process of separation of waste during the disposal. It completely gets rid of garbage on the surface which in turn eliminates bad odor, dirt. Leachate generation is also put to an end using this system.

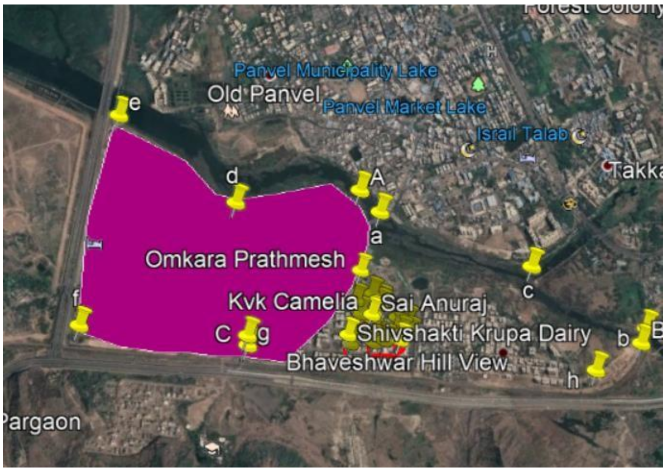

Fig. 10: Sector 1,2,3, Karanjade

Sector 1,2,3 is a newly developing area and there is scope for pneumatic waste collection system setup. Hence this area is taken into consideration.

3.2.1 DESIGN OF PNEUMATIC SYSTEM:

Air can carry substantial matters under appropriate conditions. hence the pneumatic waste conveying system is based on the physical principle of air. A stress distinction is created among the inlet and outlet of the pipe. This will cause air to flow in the pneumatic system. For the smooth conduction of solid waste, the force of airflow must be much greater than the forces acting on the waste (eg: friction, weight, inertia, etc.) The ideal velocity of airflow to transport all wide range of MSW from the point of generation to the transfer station is around 18-23m/s [4]

Fig. 11: Ideal smart city

3.2.2 HOW THE SYSTEM WILL WORK?

The series of waste starts at the source of origin (eg. condo or office building), wherein the waste is segregated into biodegradable waste and non-biodegradable waste through the citizens and is positioned thru the respective hopper door right into a vertical pipe known as a waste chute. Due to the force of gravity, the waste will reach the bottom of the building where a holding chamber is constructed above the discharge valve. The discharge valve is connected conveying pipes to the transfer station, located approximately 2-2.5 km away. At the transfer station, negative pressure will be generated in the pipe through highly controlled vacuum exhausters, ensuring that all the waste is sucked up when the discharge valve opens. The solid waste travels from the discharge valve at a speed of up to 80km/hr. to the transfer station. The segregated waste (biodegradable and non-biodegradable) will arrive at the transfer station and the non- biodegradable will be further segregated into recyclables, toxic waste, e-waste by limited laborers. the recyclables are further separated and sent to the material recovery facility (MRF). Furthermore, the volume of biodegradable waste is reduced with the **useful resource** of a compactor that compresses the waste into containers.

Fig. 12: Hypothetical model of pneumatic waste collection system

The biggest concern faced by any governing authority is properly managing leachate production which can harm our ecosystem. The pneumatic system is the solution for the above concern.

4. EXPECTED OUTCOMES

Fig. 13: Leachate formation due unsegregated waste

50-75 % of the amount of annual MSW budget is allocated only for waste collection. In a traditional waste collection system, the waste trucks are used to collect waste from all the dustbins located in a particular area (irrespective of whether it is half-filled, quarter filler, or entirely filled) which was then transported to the transfer station. This led to unnecessary trips to the dustbins which weren't even full, resulting in fuel and time consumption, CO2 emission, economic and public health cost. Our alternative waste collection system focuses mainly on route optimization.

IoT-primarily based totally waste collection system for Karanjade sector 4, 5, 6 will allow the municipal authorities to constantly screen the real-time reputation of the bins placed at unique places and as in step with the wishes take applicable movements to collect it correctly and efficiently. Hence route optimization will play a vital role to achieve the ultimate goal of the project. While on the other hand, Pneumatic Waste Collection proposed for Karanjade sector 1, 2, 3, will solve the issue of public littering, traffic, and leachate. Both the proposed systems (IoT and Pneumatic Waste Collection System) are highly essential to nurture public health as well as a green environment. [5]

5. CONCLUSION

In the 21st century, advancements in innovation and technology have made human life quite easy. [6] Increasing population and changes in the living standards of people have led to the generation of solid waste tremendously, hence an innovative and technological approach needs to be adopted when dealing with it. The main aim of our project is to give smart solutions to build a smart city that is environmentally sound and sustainable. 90% of the system is automated and hassle-free so it reduces human error to a great extent. Optimization of power would be a challenge when implemented on a large scale. This project aims to achieve the SDG (Sustainable Development Goals) as well as the 3R approach. Future is technology, so we must come up with a smart solution to create a smart city.

Fig. 14: Smart city

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