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SMART TRASH MANAGER

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Abstract: Increasing population and density are making conventional garbage collection procedures inefficient. Overflowing public bins harm both people and nature. This paper presents a Smart Trash Manager System which solves these problems by using a centralized system integrated with IoT. It enables live monitoring of bin levels, their GPS location, and automated alerts before reaching capacity of bins. The developed system works with smart bins which have a Node MCU microcontroller. Smart bin uses ultrasonic sensors for filled level data, GPS module for geolocation and Twilio for SMS Alerts to respective worker. The alerts are also visible on system dashboard which is overviewed by Municipal officer, from the office. The Software Interface have multiple functional pages including but not limited to live bin statuses in an interactive map, worker data analytics, live bin monitoring list, attendance. The solution also considers municipal corporation workers and supervisors by providing a centralized system, thus streamlining the collection process, resulting in saving time and energy.

Index Terms **- Internet of Things (IoT), Municipal solid waste, Smart Cities, Smart waste management, Sustainability**

I. INTRODUCTION

In today's rapidly urbanizing world, domestic waste generation has seen an unprecedented surge due to the growing urban population [1] and the changing consumption patterns of modern society. As cities expand and consumerism rises, waste management becomes a pressing challenge for municipalities, particularly in maintaining cleanliness and ensuring efficient disposal systems. The improper handling of domestic waste results in not only environmental degradation but also serious health risks [1], [3]. Various approaches toward smart and sustainable waste management have been explored in recent studies [5]-[9].

Traditional waste management systems, while effective to some extent, are becoming overwhelmed by the sheer volume of waste being produced. Overflowing garbage bins, inefficient collection routes contribute to pollution, ecosystem-harm, and spread diseases. As a result, there is an urgent need for smarter, more sustainable approaches to waste management, which takes us closer to the concept of Smart Cities. Due to the increasing burden on municipalities, a centralized system is needed, to relieve the burden. Hence to relieve this burden, smart trash manager system was developed.

II. LITERATURE SURVEY

Alsalama et al [1] presented a paper which was a survey-based case study paper. It conducted public surveys and domestic waste worker surveys to find out the awareness of domestic waste handling, the reasons for not sorting the waste before throwing into bins (for citizens) or reasons of throwing waste outside the bin. It also put light on accidents and problems faced by workers while handling such waste. Overall justifying how a city's domestic waste exponentially grows with population and older ways of waste handling will be inefficient and dangerous, further stating need of newer, sustainable methods.

Dubey et al [2] proposed a two-level solution model, where level 1 was house level and level 2 being society level. On the house level, a smart bin with two compartments was introduced which had automated lid opening via proximity sensors and actuators. The two compartments were for biodegradable waste and non-biodegradable waste. It included manual moving of bin, in or out of house, when predefined filled-level of either compartment is detected, it also had poisonous gas detectors and certain alert message mechanism. On the societal level, i.e. level 2, it had two outcomes, linked with level 1. Biodegradable waste from level 1 was mixed with fallen leaves waste, roots, earthworms, etc. to make compost, which can be sold or picked by municipal org. The second part of level 1, non-biodegradable waste is spread on a conveyor belt for second level segregation. It separates it into Iron, Plastic, and other waste. Further waste segregation was not possible with this model. This work suggested a mix of societal discipline and smart bin-conveyor belt model.

Qumar et al [3] focused on solid waste management of India, its challenges, and opportunities. It reviewed collection and transportation of waste, its disposal and treatment methods too. It shed light on all types and composition of wastes, statistics of waste generation of all states and their growth with help of statistical diagrams. It suggested that, community engagement, community awareness, technological innovations and integrated waste management approaches are the strong opportunities for sustainable solid waste management in India.

Ahmed et al [4] presented an IWMS (Intelligent Waste Management System) integration, which combines smart technologies to improve safety and reduce environmental impact for waste handlers and citizens. It had key objectives like Optimizing energy consumption, reducing data loss from smart bin sensors, and enhancing overall waste management efficiency. It showcased three phases, where phase 1 was Clustering Smart Bins by using the AHA-LEACH algorithm for minimizing energy usage and better cluster management. Phase 2 had addressed missing data by employing AHA-KNN approach, by filling missing data. Phase 3 had optimized waste truck routing optimization by MOAHA algorithm.

We have seen the need of newer methods in waste management and the current scenario of waste handling in several studies. Also, the usage of IoT based smart bins or methods we studied were showing a lack of a centralized user interface for Municipal corporations to ensure the smooth flow of waste. The systems should consider all personnel involved in domestic waste management. This helped in deciding the main objectives of research.

III. PROPOSED METHODOLOGY:

Based on the findings from the Literature Review, existing systems lack some aspects. To address these gaps, the smart trash manager system is designed with the following objectives:

- To create a Centralised System for Municipal corporation for waste management and workers' data
- To create a User Interface for real time monitoring of Bins
- To provide real time waste level information.
- To provide automatic alerts of waste levels exceeding the norm.

The Smart Trash Manager System was designed for scalability, real-time data processing, and efficient integration. The chosen technologies ensure optimal performance:

- Frontend (ReactJS, NextJS, Leaflet): ReactJS enables modular UI development, while NextJS improves performance with server-side rendering. Leaflet provides lightweight, real-time GPS mapping.
- Middleware (Prisma): Chosen for its scalability, type safety, and simplified PostgreSQL integration.
- Database (Firebase): Reliable, Scalable, and supports real-time Sensor and GPS data
- Database (PostgreSQL): Front-end data handling and analytics
- Containerization (Docker): It ensures environment consistency, simplifies deployment, and enhances scalability.
- Hardware: NodeMCU acts as the microcontroller, processing sensor data. Ultrasonic Sensor detects the fill level of the bin. GPS Module provides real-time location tracking.

The hardware and sensors were selected by considering the availability, price, and complexity of components.

System Architecture:

The System Architecture of the Smart Trash Manager System is Shown in below fig.1.

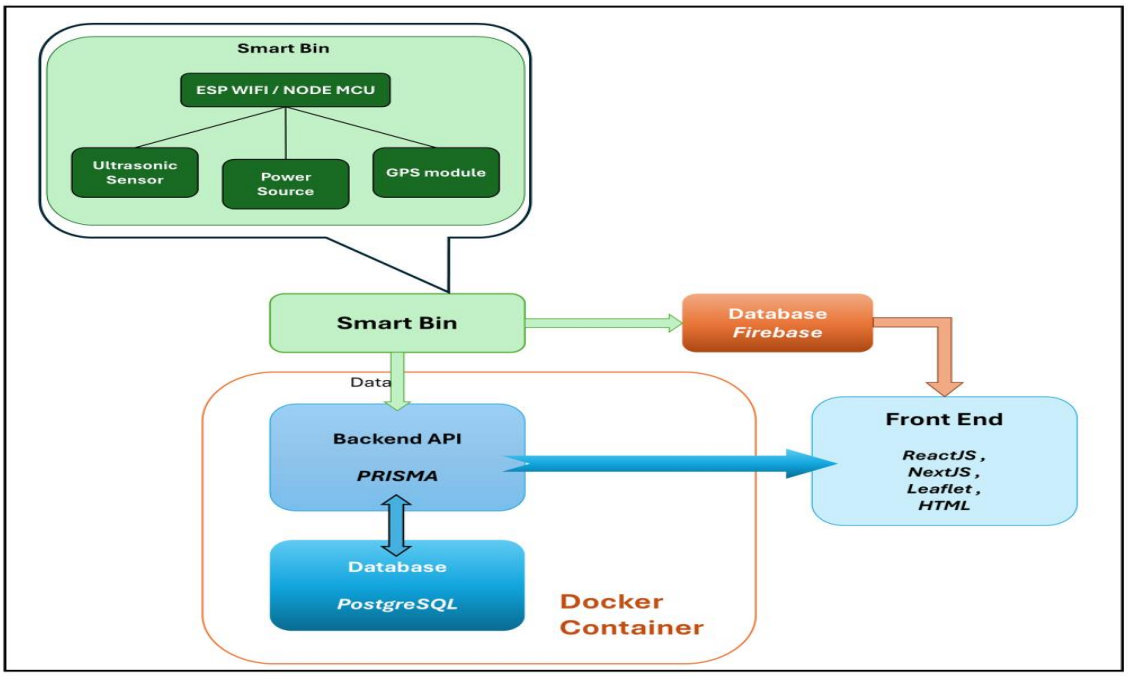


fig 1. system architecture diagram

The Architecture of Smart Trash Manager, from above diagram, involves the Smart Bin, Front End, Back End, and Databases. It is a three-tier architecture consisting of Hardware, Middleware and Front-end.

a. Smart Bin: smart bin has Node MCU controller, Ultrasonic sensor, Power Source and GPS Module
b. Database: Two databases, Firebase and PostgreSQL are used. Firebase for all live sensor data storage and showcase on dashboard, while PostgreSQL used to store the worker data and all other front-end data. It also has strong data analysis capabilities.
c. Middleware: Prisma is used and backend API used for simple PostgreSQL integration, inside a docker container for ease in scalability and continuous flow. The docker container ensures seamless data flow in scale-up scenario.
d. Frontend: ReactJS, HTML, NextJS, Leaflet is used in front end, for attractive and user-friendly UI, with high functionality.

The fig 2. illustrates the circuit connection diagram of smart bin. It consists of Node MCU microcontroller also known as ESP8266, ultrasonic sensor which sense the filled levels and GPS module along with its antenna. The power is provided from a 5V power source to the Node MCU which further distributes it to GPS module and Ultrasonic sensor. The diagram is made with the help of Fritzing Software.

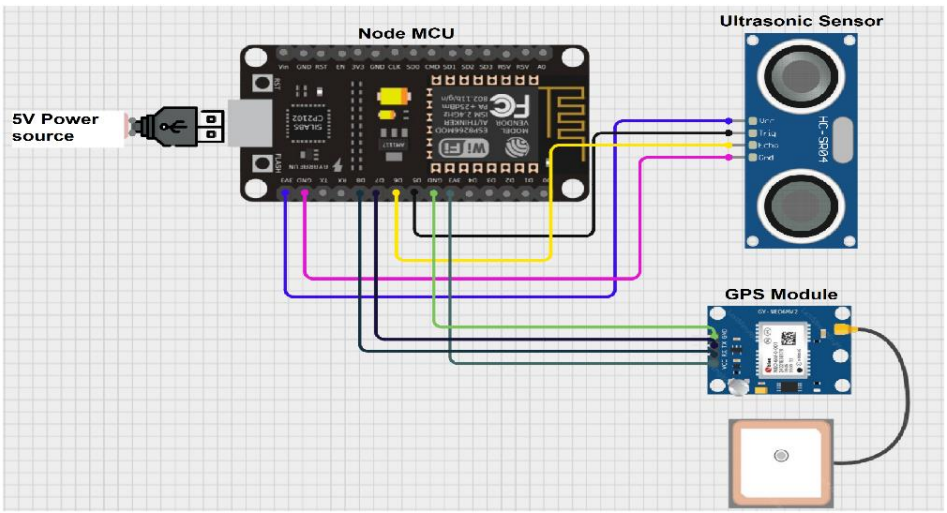


fig.2 circuit diagram

Working:

The overall system process flow is shown in below fig.3, which covers the main working of the system.

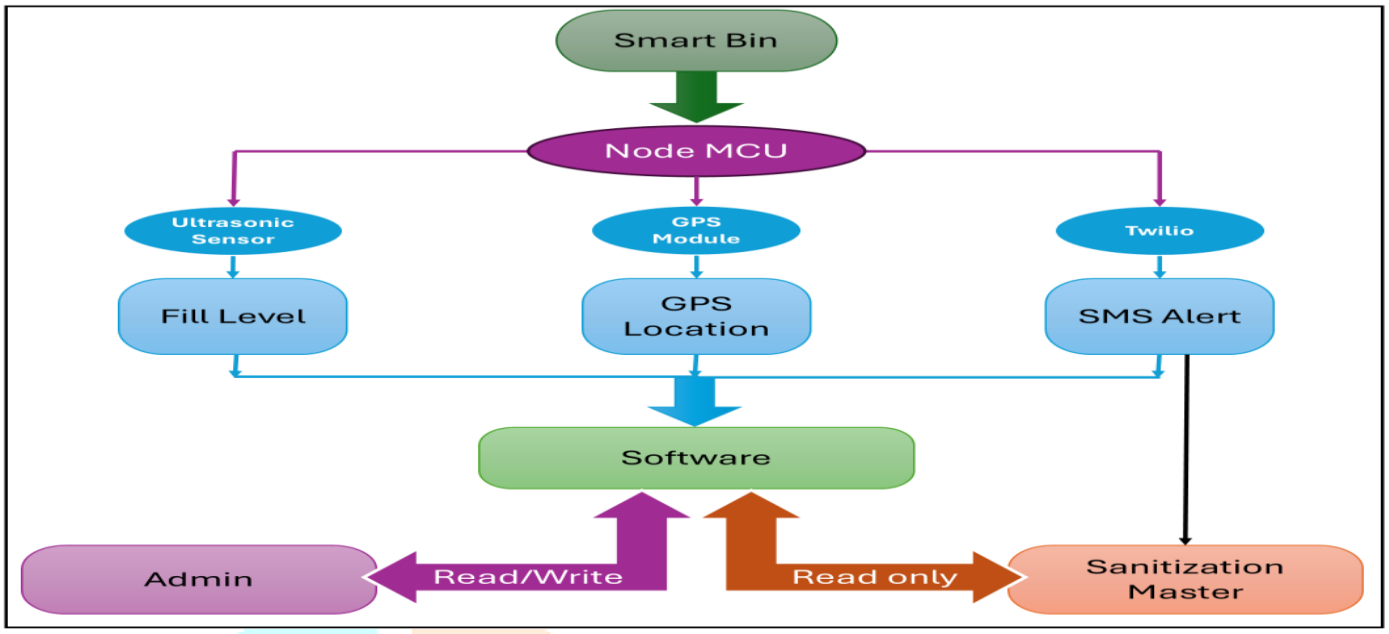


fig.3 system workflow

The working of Smart Trash Manager System starts from the Bin. Smart Bin have a Power Source. It also has Node MCU, also known as ESP8266, which controls two elements – Ultrasonic sensor & GPS module. Ultrasonic sensor measures waste bin filled level by sending and receiving ultrasonic signals and computing. GPS module sends GPS Location in the form of Latitude and Longitude coordinates to dashboard via firebase. Node MCU also sends data to Twilio, which sends SMS alerts when certain level is achieved by the waste inside the bin. This SMS alert is directly sent to the assigned Sanitization Master. All the data is live data and it is shown on dashboard of centralized software. The software is available to Admin and Sanitization Master (worker supervisor). The Admin have read-write access to software, while Master have read only access. Master or Sanitization Master is present with garbage truck. When the sanitization master and ground worker reach the bin through the trash collecting truck, the ground worker empties the bin into the trash collecting truck and the truck follows its usual routine back to the dump facility or recycle facility. The whole Smart Trash Manager system is designed to target all the roadside public garbage bins, from which Municipal Corporations' Garbage trucks collect garbage. These bins are in both small and large sizes

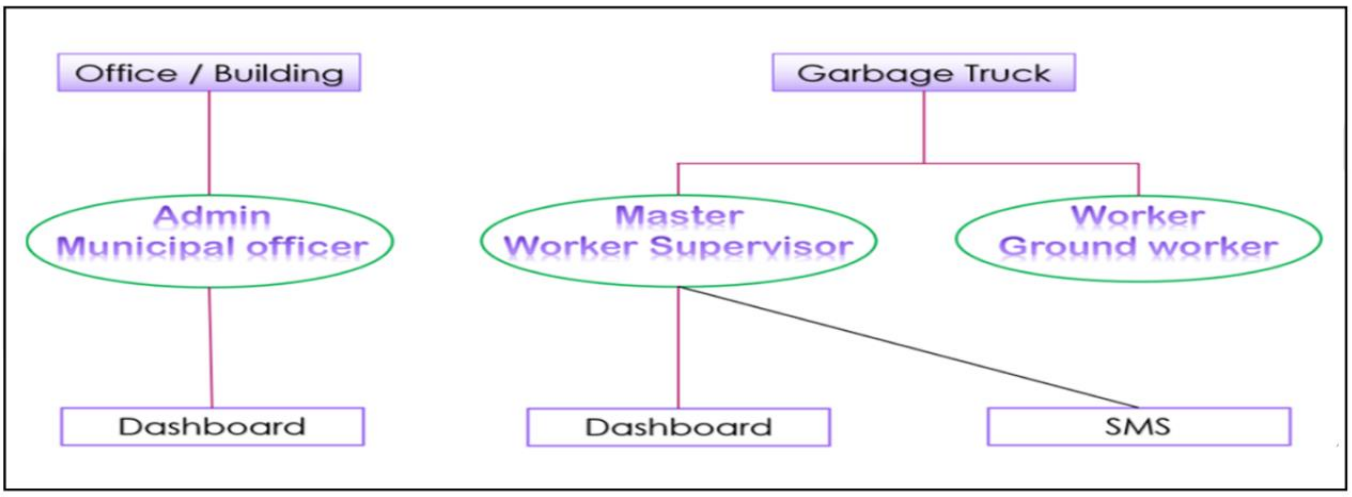


fig.4 hierarchy diagram

There are people from multiple levels of hierarchy involved and have different roles. These can be understood by the above Fig 3. Hierarchy Diagram. Hierarchy clarifies the roles of each personnel. The most important person is the Admin, who is ideally a municipal officer, who controls and monitors everything from the office building. Admin have all read-write access of dashboard, and he oversees the sanitization masters

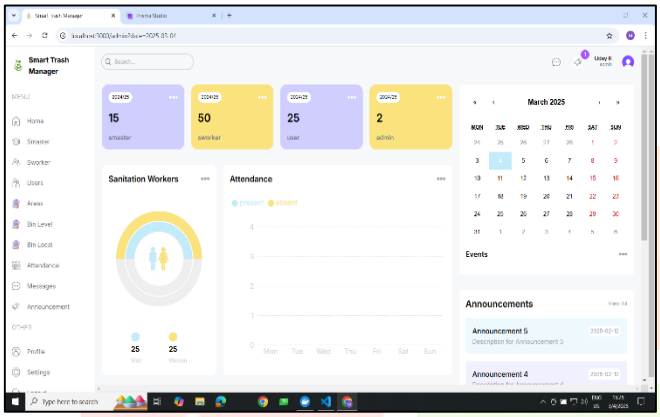
& workers. Attendance, updates, announcements, work status of all the region under admin, garbage collection patterns, generation patterns, statistics are all available to the Admin.

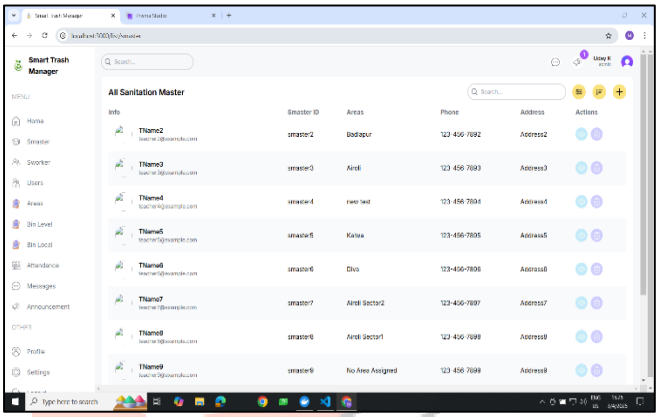
After admin, Sanitization Master is responsible in the system. Sanitization master is a Worker supervisor, generally having higher experience than most workers. Sanitization Master or Master also manages certain number of workers, their task allocation, attendance, etc. Sanitization Master is Present in the Garbage Collection Trucks along with ground workers.

Ground Workers are the on-site workers who are responsible for cleaning tasks, emptying bins into garbage trucks when they arrive, drive garbage truck or other actual cleaning tasks in city.

IV. Results and Discussion:

The Smart Trash Manager System was tested for real-time data accuracy, GPS tracking efficiency, and system response time. The results indicate that the system effectively detects bin fill levels and provide accurate geolocation updates. A Prototype Smart Bin was created, having all the required Hardware components. The Smart Bin and the software is integrated together. Figure 4 shows the Home page of the Software dashboard, which have total count of Workers, S Masters, civilians, etc in the system. It also has easy access calendar, announcements, attendance, and other data analytics. There is also a side panel for visiting other pages and



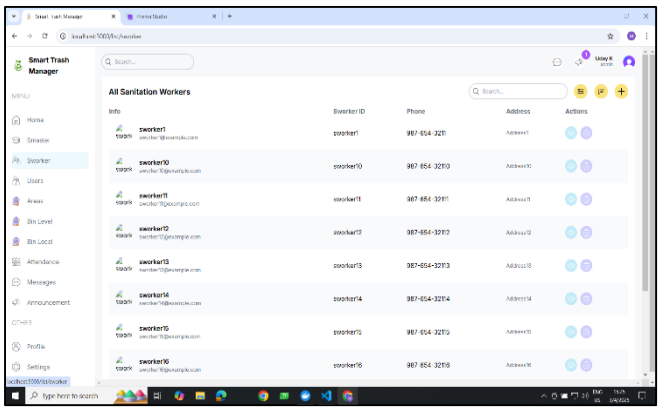


functionalities within system. Next figure, fig.5, shows the S Masters page. On this page we can see all S Masters, admin is able to add, delete, edit, sort, filter, search from the whole list. This list has Sanitization master details like name, id, area, phone and more.

fig 5. Home Page

fig 6. S Master Page

The next figure, fig.6 shows the Workers page, which have the list of all the Ground Workers in the system, along with their id, phone, and address. Fig. 7 shows the 'Users' page which shows the list of Civilians who are registered in the system. These are the interested civilians which can be only added by admins, they can view the worker and master allotted to their region.



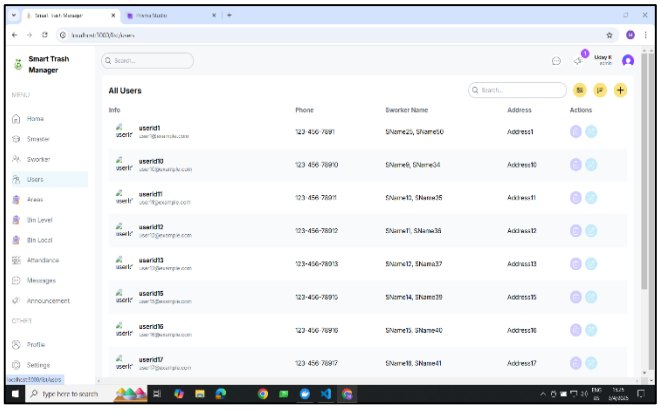


fig 7. workers page

fig 8. S master page

The next page is Areas Page shown in Fig.8. It shows the list of all areas registered on system, in the region. Assigned S Master and Tasks are also visible.

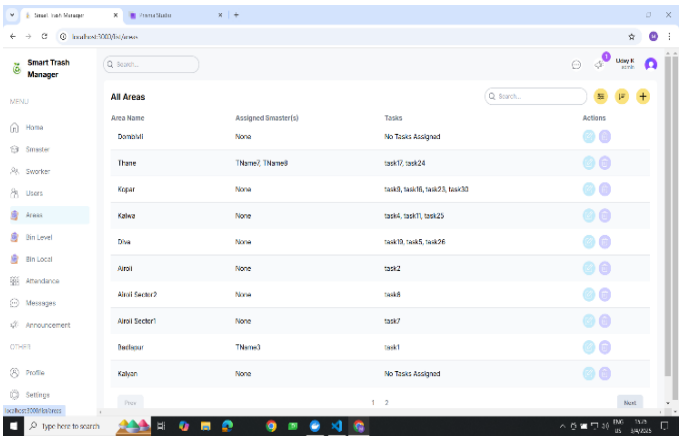


fig 9. areas page

Next Page is Bin Level page, shown in fig.9 and 10. This page shows the registered Bins in a List format. This is the Live monitoring list and resembles the current bin fill level. Along with bin, bin id, assigned S Master and Area is also visible. If the garbage level is above specific level, the bin level indicator gets red in colour and a pop-up alert for the bin is visible. This can be seen in figure 9 & 10

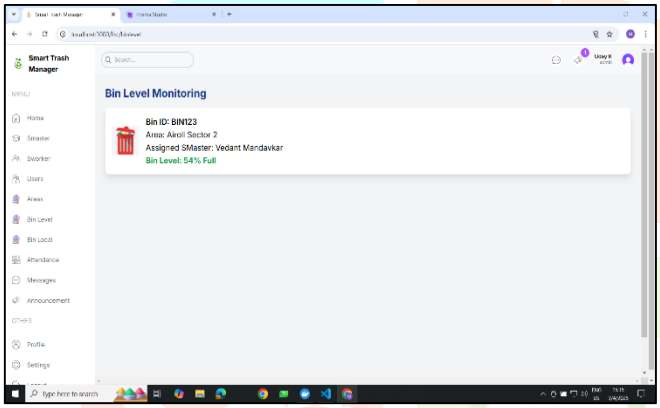


fig 10. Bin level page case 1

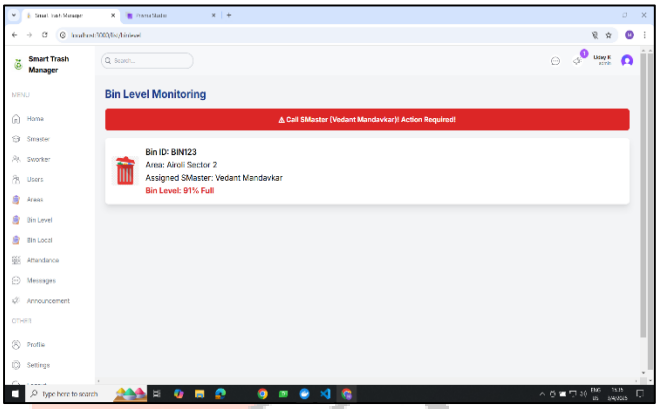


fig 11. Bin level page case 2

The next page in system is the ‘Bin Local’ page, shown in figure 11,12 & 13. In this page, we can add new Bins in the system. This page also has the Live Map of the bins. The bins can be seen on map by their Markers This page also gives the live status of bins with map location. When the bin fill level is low, the level indicator text colour and number are green in colour. The marker on map is also green in colour, as seen in fig.11.

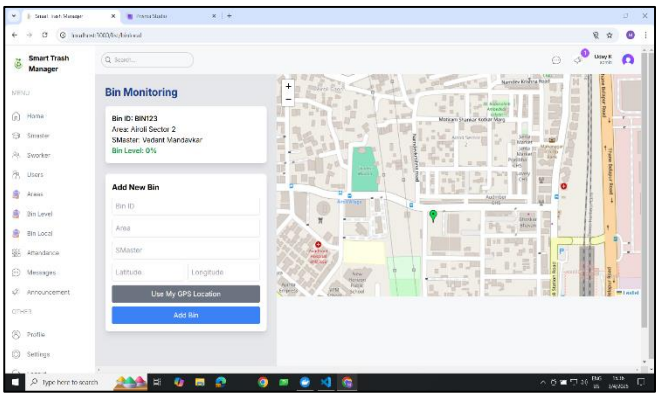


fig 12. bin map page case 1

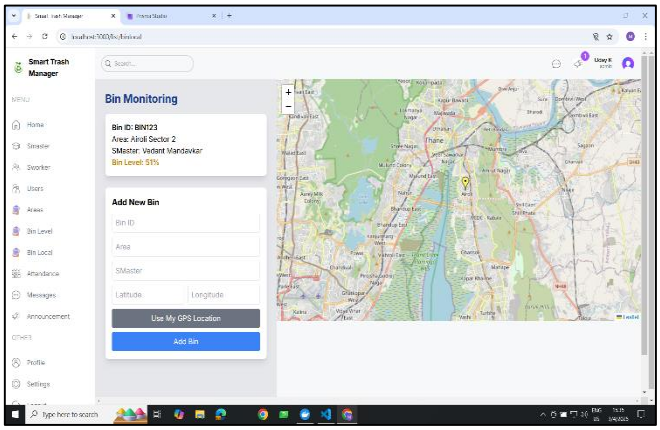


fig 13. bin map page case 2

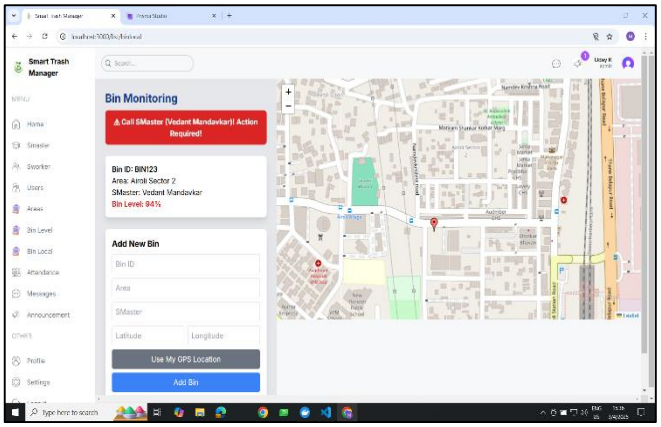


fig 14. bin map page case 3

When the bin fill level is medium, the level indicator text colour and number are yellow in colour. The marker on map is also yellow in colour, as seen in fig.12. The marker colour and level indicator text colour get red in colour when a certain limit of bin fill level is achieved. A pop-up alert notification is also seen in such case. This is shown in fig.13. All the pages above were the core functionality of the system. There are also more features in the system, in next pages.

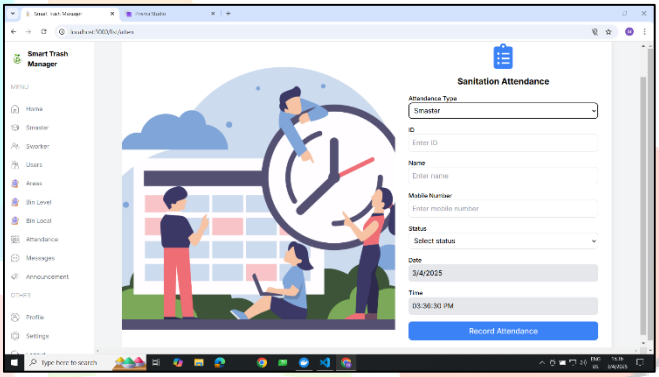


fig 15. attendance page

There is the Attendance page for marking of attendance, shown in fig.14. One can enter their role, id, name, number, status, and date & time in this page. Role can be S Master or Worker or Admin.

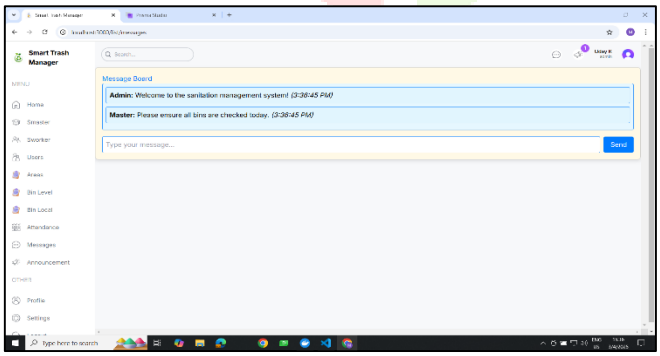


fig 16. Messages page

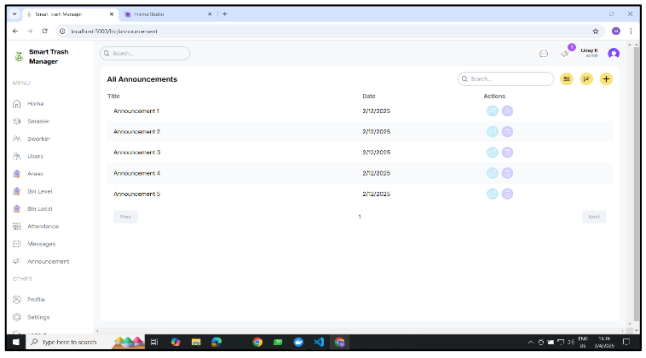


fig 17. Announcements page

The above page, in fig.15, shows messages page, where admin, master, workers can send messages. The messages show with time stamp. There is also an announcements page, seen in fig.16, where admin can send important announcements, and all others can view it. It could be any work-related announcement like change in routes, schedules, over time requirements or other work.

The results show that the Smart Bin Correctly works, monitors filled-level, sends GPS location and sends SMS alerts. The System is able to handle, organize and monitor both working people and the garbage bins all over a city. The system ensures that garbage collection process gets more efficient, the problem of garbage bin filling completely and overflowing, is eliminated, thus avoiding all its adverse effects.

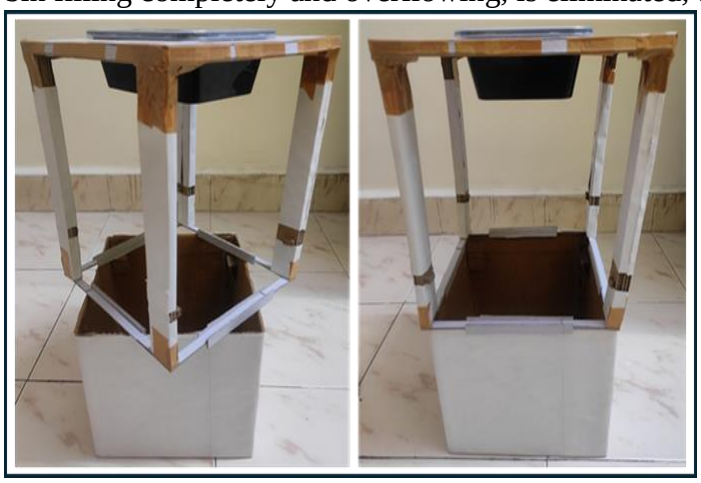


fig 18. Smart bin prototype image 1

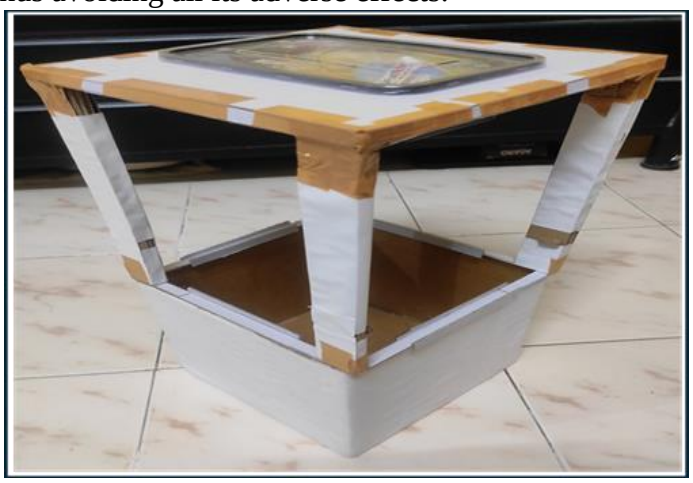


fig 19. Smart bin prototype image 2

We can see the Smart bin prototype in fig. 17 and fig. 18. The Black box has all the Hardware Components and battery or power source in it. It is kept such that the Ultrasonic sensor's sender and receiver nodes are facing the inside of bin and the GPS antenna is facing upwards to sky. The black box has transparent top cover which protects the IoT components from rainwater but also provides signal to pass through it. The prototype showcases a type of bin cover, which can adapt to existing bins, eliminating the need to replace whole bins, just the cap needs to be replaced. This design allows to throw garbage from all four sides. This adaptive cap can be taken out when the worker empties the bin's contents into the trash collecting truck. After emptying, the cap can be placed again on top of bin.

V. Conclusion and Future Scope:

This study developed a smart trash manager system integrating IoT and GPS for real time waste monitoring. The objectives set at beginning, including developing a centralised system for municipal corporations which can provide real time waste level information and automated alerts, were successfully met through proposed system. The proposed system took a step towards sustainable solution for domestic waste management. Future work could involve integrating machine learning algorithms into routing trucks, predicting patterns of garbage generation and plan accordingly. Also expanding the system into a larger geographic area, can be scope of future. The Hardware components used could be also scaled-up in terms of cost and capabilities.

Funding:

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