SMART WASTE MANAGEMENT SYSTEM USING QR CODE AND GIS

PROJECT REPORT

As part of Internship by TPLC
In collaboration with SCTL and ICCC

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Abstract

Rapid urbanization and increasing population density in cities like Thiruvananthapuram have led to significant challenges in managing municipal solid waste effectively. Traditional waste collection systems often suffer from inefficiencies such as missed pickups, overflowing bins, and lack of real-time data, which contribute to public health issues and environmental degradation. To address these issues, this project introduces a Smart Waste Management System that leverages Geographic Information System (GIS) mapping, QR code technology, and a role-based web application to streamline and optimize waste collection and monitoring processes.

The proposed system categorizes users into three roles: first-level workers (Haritha Karma Sena), second-level waste collectors, and administrative authorities. Each Material Collection Facility (MCF) is assigned a unique QR code. When first-level workers deposit waste, they scan the corresponding QR code, which updates the GIS-based map interface by changing the MCF's color status to red, indicating it is full. Second-level collectors, upon collecting waste from the MCF, scan the same QR code to revert the status back to green, signifying it is empty. These real-time updates enable efficient monitoring and transparency in waste collection operations.

The web application includes route optimization features, allowing workers to identify and follow the most efficient paths between MCFs. Administrators have access to a dashboard that displays the live status of all MCFs on an interactive map, thereby facilitating data-driven decisions and better resource management. By combining spatial mapping with a role-based control system, this project aims to reduce operational redundancy, improve waste pickup accuracy, and promote a cleaner urban environment.

1 Introduction

Efficient waste management plays a vital role in ensuring the sustainability and livability of urban areas. With rapid urbanization and population growth, cities like Thiruvananthapuram are facing increasing challenges in managing municipal solid waste. The conventional waste collection practices are often unstructured, resulting in delayed pickups, overflowing facilities, and inefficient use of resources. These problems not only impact the environment but also pose significant health risks to residents.

To address these issues, this project introduces a smart waste management solution that leverages modern technologies such as Geographic Information Systems (GIS), QR code verification, and role-based monitoring via a web application. By integrating these technologies, the system aims to provide real-time tracking, efficient route planning, and improved transparency in the waste collection process. This solution facilitates proactive decision-making by the authorities and streamlines the daily operations of waste collection staff.

Objective:

- To conceptualize and implement a smart waste collection and monitoring system tailored for urban environments using modern geospatial and web technologies.
- To utilize GIS (Geographic Information Systems) mapping for real-time visualization and location-based status monitoring of Material Collection Facilities (MCFs) across the city.
- To design a role-based login framework that categorizes users into three levels—first-level field workers (Haritha Karma Sena), second-level collectors, and system administrators—ensuring user-specific access and control.
- To integrate QR code scanning at MCFs for field workers to update the waste status directly, enabling seamless communication between different levels of users and reducing manual reporting.
- To develop a user-friendly web interface that allows visualization of MCF locations, color-coded waste status, and optimized collection routes, improving operational efficiency and decision-making.

Scope:

- To monitor the status of Material Collection Facilities (MCFs) through an interactive map interface, ensuring real-time waste level updates and better response planning.
- To track the activity and movement of waste collectors using a role-based dashboard, thereby increasing accountability and improving task allocation.
- To enable optimized collection routes for waste workers, minimizing travel time and fuel consumption while ensuring that full MCFs are prioritized.
- To enhance the transparency of operations by providing live data to administrators, reducing the risk of human error and inefficient coordination.
- To build a scalable and adaptable system that can be replicated in other urban centers with minimal modifications.

2 Methodology

This project was implemented using a combination of geospatial tools, web technologies, and a role-based access control model. The methodology focuses on mapping, monitoring, and optimizing waste collection processes using real-time updates and interactive dashboards.

Tools & Technologies Used:

- **Programming Languages:** Python, HTML, JavaScript
- **Backend Framework:** Flask (Python Web Framework)
- **GIS Mapping Tools:** Leaflet.js integrated with OpenStreetMap
- **QR Code Integration:** JavaScript-based webcam scanner
- **Database:** SQLite or Firebase (assumed for prototype)
- **User Interface:** Web-based dashboards with role-specific access

Workflow:

1. **Login System:**
   The system provides a role-based login mechanism where users are authenticated as one of three types:
   - First-level users – Haritha Karma Sena (field waste collectors)
   - Second-level users – Vehicle-based collectors
   - Admin – Authorities with dashboard access
2. **GIS Mapping:**
   A digital map of Thiruvananthapuram is displayed using Leaflet.js. Material Collection Facilities (MCFs) are marked on the map with color-coded icons:
   - greenGreen – Empty MCF
   - redRed – Filled MCF

3. **QR Code Integration:**

   Every MCF is assigned a unique QR code. First-level workers scan the QR after dumping waste, which marks the corresponding facility as red (full). Second-level collectors scan the same code after collection, reverting the status to green (empty).

4. **Route Tracking:**

   The interface provides route optimization features for first-level workers. By clicking "Start Route", the map highlights the optimal collection path between MCFs.

5. **Admin Monitoring:**

   Administrators can view a real-time map dashboard that displays the current status of all MCFs. This enables oversight of worker activity, identifies collection delays, and supports efficient resource allocation.

3 Implementation

The implementation of the Smart Waste Management System focuses on three user roles: first-level workers, second-level collectors, and administrators. Each role is supported by an intuitive interface tailored to its specific functions. The web application facilitates login authentication, QR code scanning, map interaction, and status monitoring.

Login Page:

- The login page includes fields for Email and Password along with a dropdown to select the user role.
- Upon successful authentication, users are redirected to their respective role-specific dashboards.

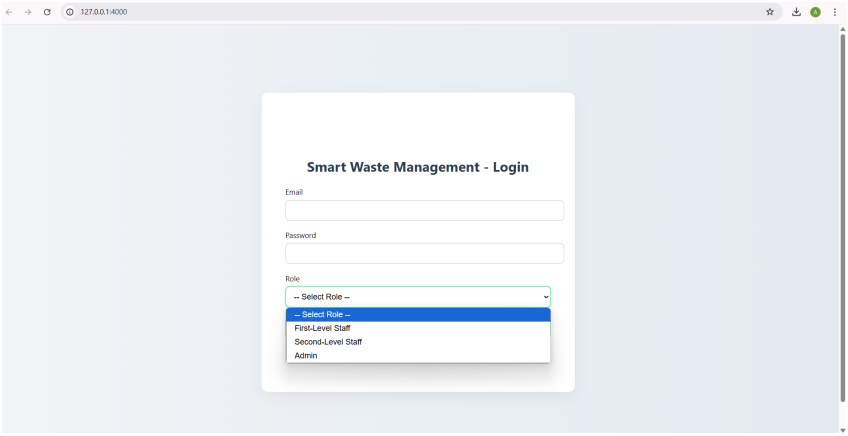

Figure 1: Login Page Interface

First-Level Worker Interface (Haritha Karma Sena):

- The ”Start Route” button highlights the optimal collection path across multiple MCFs using the integrated map.
- The ”Start QR Scanner” button activates the device’s camera, allowing the user to scan the QR code of the MCF after depositing waste.
- Once scanned, the corresponding MCF on the GIS map changes status from greengreen (empty) to redred (full), indicating that it is ready for second-level collection.

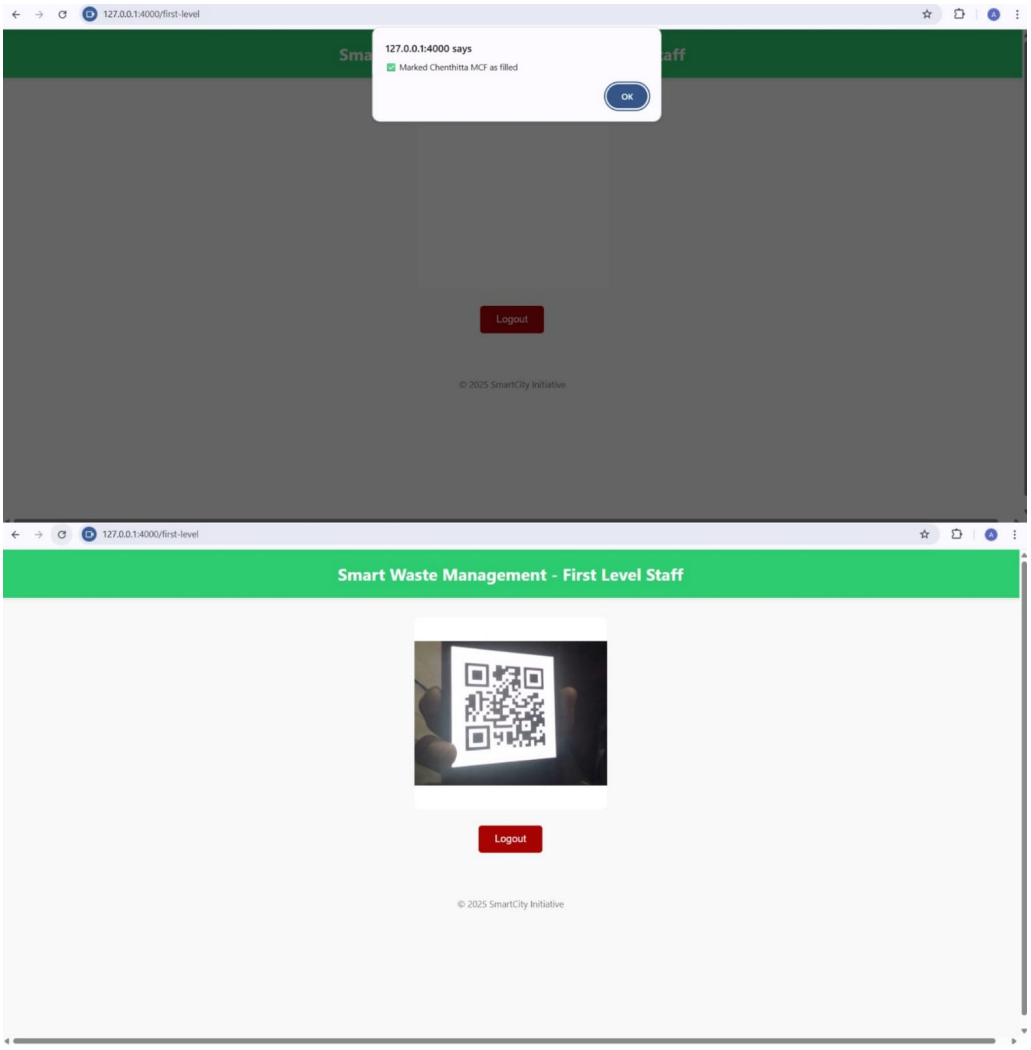

Figure 2: First-Level Staff Interface (Haritha Karma Sena)

Second-Level Collector Interface:

- Second-level users access a map with highlighted full (red) MCF's based on updates from first-level workers.
- After collecting the waste from a red-marked MCF, the user scans the same QR code to revert the MCF status from red to green.
- This action reflects in real-time on the admin dashboard.

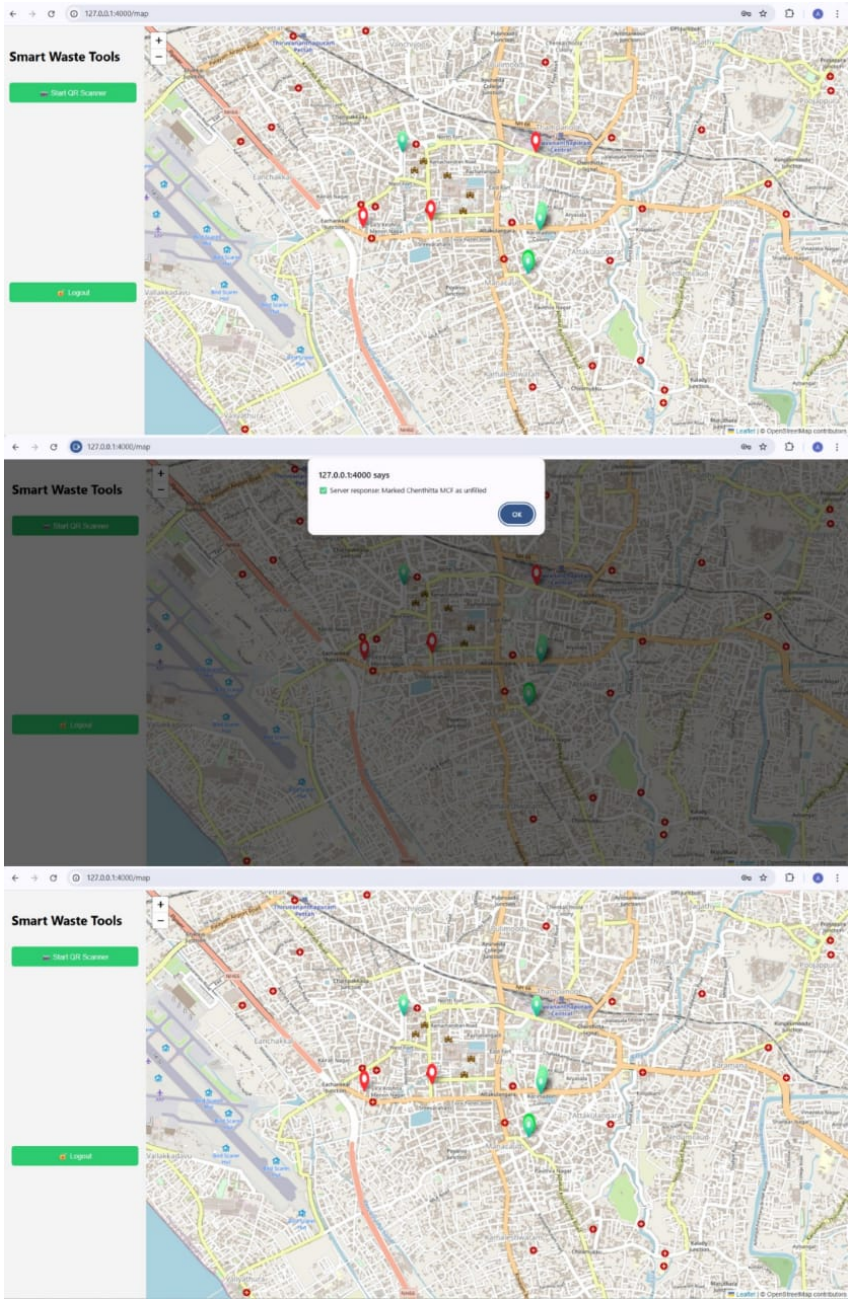

Figure 3: Second-Level Collector Interface

Admin Panel:

- The administrator dashboard displays a real-time interactive map of all registered MCFs in Thiruvananthapuram.
- MCF's are color-coded based on their current status: greengreen for empty, redred for full.
- Map tools such as zoom, pan, and legend are included for better usability.

- Additional overlays and filters allow administrators to track user activity and optimize response efforts.

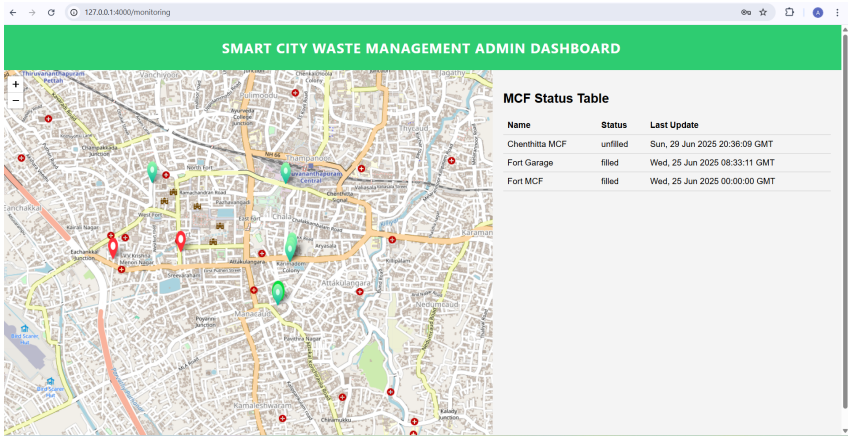

Figure 4: Admin Dashboard Map View

Google Earth Pro and QGIS:

The initial stage of the project involved using Google Earth Pro to delineate the ward boundaries of the selected region in Thiruvananthapuram. Based on geographic coordinates, key waste management points such as Material Collection Facilities (MCFs) and the Resource Recovery Facility (RRF) were accurately marked. These features were saved and exported in KML format for further processing.

The spatial data was then imported into QGIS, where it was organized into separate layers representing ward boundaries, MCF's, and the RRF. Each layer was enhanced with appropriate labeling and symbology to clearly differentiate the types of facilities and their functions. The data was then converted into shapefile (SHP) format, ensuring compatibility with GIS-based systems and applications.

This processed spatial dataset was prepared to support the development of a smart waste management system, serving as a reliable foundation for mapping, route planning, and monitoring waste collection activities within the mapped area.

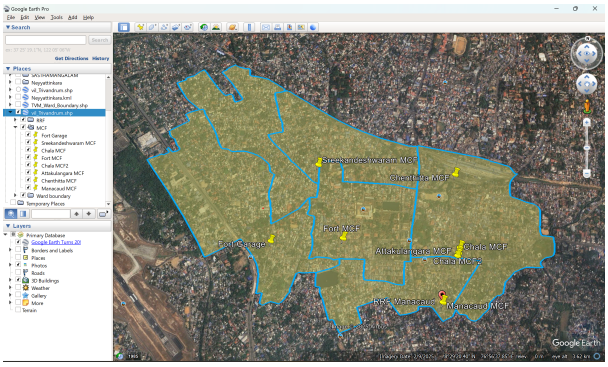

Figure 5: Google Earth Pro

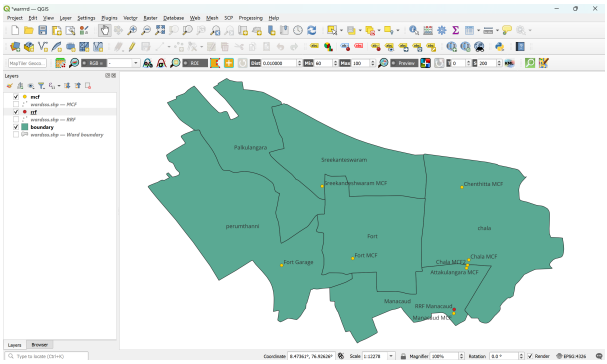

Figure 6: QGIS

4 Results and Discussion

The proposed system was tested through simulations and prototype demonstrations. The following outcomes were observed:

Effectiveness:

The system ensured timely waste collection by visually indicating the status of each MCF on a real-time map. Workers and administrators could immediately identify full facilities and plan collection accordingly.

Accuracy:

GIS-based visual cues, such as green (empty) and red (full), reduced dependency on manual updates and eliminated potential reporting errors.

User Control:

Role-based access provided clarity and security by defining permissions for different categories of users (workers, collectors, and admins).

Efficiency:

Redundant collection trips were avoided as collectors could focus on MCFs marked as full. This helped in optimizing route planning and reduced operational costs.

5 Conclusion

The Smart Waste Management System presented in this project serves as a practical and scalable solution for improving the efficiency, transparency, and responsiveness of urban waste collection. By integrating Geographic Information Systems (GIS), role-based access control, and QR code verification, the system enables real-time monitoring of Material Collection Facilities (MCFs) and ensures timely waste disposal.

This approach effectively bridges the communication gap between field workers, collectors, and administrators through a web-based platform that offers map visualization, optimized routing, and automatic status updates. The use of color-coded indicators (green for empty, red for full) simplifies the process of tracking MCF conditions, reducing manual errors and improving operational accuracy.

Moreover, the structured workflow allows for efficient resource allocation and minimizes unnecessary collection trips, which contributes to cost savings and reduced environmental impact. The system also promotes accountability by clearly defining user roles and responsibilities, making it easier to monitor performance and manage data securely.

Overall, this project demonstrates how the thoughtful application of modern web and GIS technologies can transform traditional waste management into a smart, responsive, and sustainable process suitable for implementation in smart cities across India and beyond.

6 Future Scope

While the current system is implemented as a web-based prototype, several enhancements can be made in the future to improve functionality and scalability:

- Integrate GPS tracking for waste collection vehicles to enhance real-time logistics.
- Develop a companion mobile application for on-the-go access and easier field operations.
- Automate alert systems to notify officials when an MCF is full.
- Use AI and data analytics to predict waste generation patterns and optimize resource allocation.

7 References

- Leaflet.js Documentation: https://leafletjs.com
- OpenStreetMap: https://www.openstreetmap.org
- QR Code Scanner Libraries (JavaScript): https://github.com/mebjas/html5-qrcode
- Python Flask Documentation: https://flask.palletsprojects.com

8 Appendix

The following items may be added based on institutional requirements:

- Full backend and frontend source code used for the prototype
- Sample QR codes used for identifying Material Collection Facilities (MCFs)
- Screenshots of the user interface for each role (worker, collector, admin)
- Additional GIS map layers or printed versions of map views