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Smart Digital Waste Management & Monitoring System

Dr. Para Subbaiah, CH.Bhargavi, T.Sravani, K.Prasanna, SK.Rameeja

Department of CSE, Vijaya Institute of Technology for Women, Enikepadu, Vijayawada, India.

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ABSTRACT

Rapid urbanization and population growth in developing countries like India have severely strained existing municipal solid waste (MSW) management systems, leading to environmental degradation, public health concerns, and rising economic costs. The conventional "collect and dump" approach is inefficient and unsustainable, marked by poor source segregation, unoptimized collection routes, and weak accountability among stakeholders. These challenges affect all sections of society—from citizens living in unhygienic conditions to municipal bodies struggling with operational inefficiencies—while the environment continues to suffer from increased pollution and landfill burden

To address these issues, the proposed Smart Digital Waste Management & Monitoring System offers a comprehensive, technology-driven solution that digitizes the entire waste management lifecycle. The system integrates a FastAPI-based backend with a React.js frontend, supported by a MySQL database and machine learning models (Decision Trees) for segregation compliance prediction and incentive automation. Key features include AI-driven segregation monitoring, a gamified Green Points reward system, decentralized governance through Green Champions, and end-to-end waste tracking from collection to disposal. This proactive, data-driven approach enhances transparency, encourages responsible behaviour, optimizes municipal resources, and provides a scalable, sustainable model for Smart City waste management initiatives.

1. INTRODUCTION

Rapid urbanization and increasing population density in developing countries such as India have intensified the challenges of municipal solid waste management. Cities generate enormous volumes of waste daily, overwhelming existing infrastructure and exposing the limitations of traditional "collect and dump" practices. Poor source segregation, lack of real-time monitoring, inefficient collection logistics, and weak accountability mechanisms contribute to environmental pollution, landfill overflow, and public health risks. As urban ecosystems expand, the need for intelligent, scalable, and citizen-centric waste management solutions becomes increasingly urgent.

This study proposes a Smart Digital Waste Management & Monitoring System that leverages modern web technologies and machine learning to digitize and optimize the entire waste management lifecycle. By integrating a FastAPI-based backend, a React.js frontend, and a MySQL database with Decision Tree–based predictive models, the platform enables automated segregation compliance monitoring, incentive-based behavioral change, and decentralized verification through Green Champions. The system enhances transparency, operational efficiency, and data-driven decision-making, providing a sustainable and scalable framework aligned with Smart City initiatives and future-ready urban governance.

1.1. Objectives:

The primary objective of the Smart Digital Waste Management & Monitoring System is to design and implement a comprehensive, technology-driven platform that enhances efficiency, transparency, and accountability across the entire waste management lifecycle. The project aims to address both behavioural and operational challenges through the integration of digital tools, data analytics, and community participation.

The specific objectives of this project are as follows:

1. To achieve 100% source segregation of waste through digital logging and verification mechanisms.
2. To implement mandatory citizen training modules to promote awareness and responsible waste disposal practices.
3. To enhance transparency and accountability in municipal waste management through a role-based monitoring system.
4. To optimize waste collection and scheduling processes using a centralized digital platform.
5. To leverage machine learning algorithms for segregation compliance prediction and automated incentive or penalty recommendations.
6. To encourage behavioral change through a gamified Green Points reward system.
7. To enable real-time reporting of illegal dumping and waste-related issues with geo-tagging support.
8. To ensure end-to-end tracking of waste from collection to final disposal.
9. To provide data-driven insights and analytics for improved municipal decision-making.
10. To develop a scalable and sustainable smart waste management framework adaptable to Smart City initiatives.

1.2 Principles Smart Digital Waste Management & Monitoring System

- Waste Hierarchy (3R/5R Principle)

The fundamental principle of waste management follows the hierarchy: Reduce, Reuse, Recycle (and extended to Refuse and Recover). The primary focus is on minimizing waste generation at the source before considering disposal. Prevention is always more sustainable and cost-effective than treatment.

- Source Segregation

Waste must be separated at the point of generation into categories such as biodegradable, recyclable, and hazardous. Proper segregation improves recycling efficiency, reduces landfill burden, and enhances resource recovery.

- Polluter Pays Principle (PPP)

The entity generating waste is responsible for its proper disposal and associated costs. This principle encourages accountability and promotes environmentally responsible behavior among citizens and industries.

- Sustainability and Environmental Protection

Waste management systems must aim to minimize environmental impact by
reducing greenhouse gas emissions, preventing soil and water contamination, and conserving natural resources.

- Integrated Waste Management (IWM)

A comprehensive approach combining waste reduction, recycling, composting, energy recovery, and safe disposal. This ensures that waste is managed systematically across its entire lifecycle.

- Resource Recovery and Circular Economy

Waste should be treated as a resource. Materials and energy should be recovered wherever possible, promoting a circular economy where products and materials are reused instead of discarded.

• Public Participation and Awareness

Effective waste management depends heavily on community involvement. Citizen engagement, awareness programs, and behavioral change initiatives are essential for long-term success.

• Transparency and Accountability

Monitoring, tracking, and reporting mechanisms should be implemented to ensure compliance, reduce illegal dumping, and improve governance efficiency.

1.3 Process Involved:

Waste management is a systematic process that ensures waste is handled efficiently from its generation to final disposal. It involves several interconnected stages designed to minimize environmental impact and promote sustainability.

1.Waste Generation

Waste is produced from households, industries, hospitals, markets, and institutions. The type and quantity of waste depend on lifestyle, consumption patterns, and economic activities

2. Segregation at Source

Waste is separated into categories such as biodegradable (wet waste), recyclable (dry waste), and hazardous waste. Proper segregation improves recycling efficiency and reduces landfill burden

3. Collection

Segregated waste is collected through door-to-door services or community bins by municipal authorities or authorized agencies. Regular and systematic collection prevents public health risks.

4. Transportation

Collected waste is transported using covered vehicles to processing centers or transfer stations. Efficient route planning reduces fuel consumption and operational costs.

5. Processing and Treatment

Waste is sorted and treated based on type:

- Recyclables Recycling industries
- Hazardous waste Specialized treatment
- Combustible waste Waste-to-Energy plants

6. Final Disposal

Non-recyclable and non-recoverable waste is disposed of in sanitary landfills designed to prevent soil, air, and water pollution

7.Monitoring and Regulation

Authorities monitor the entire system to ensure compliance with environmental regulations, prevent illegal dumping, and improve efficiency.

1.4 Operating Conditions:

Operating conditions refer to the environmental, technical, and functional requirements under which a waste management system operates efficiently, safely, and sustainably.

1.Environmental Conditions

- Temperature and climate variations (heat, rain, humidity) should not disrupt collection or processing.
- Proper ventilation and odor control must be maintained at processing units.
- Landfills must be designed to prevent groundwater contamination and methane leakage.

2. Infrastructure Conditions

- Availability of proper waste bins for segregation (wet, dry, hazardous).
- Covered transportation vehicles to prevent littering and spillage.
- Functional processing facilities such as composting units, recycling centers, or WTE plants.
- Reliable electricity and internet connectivity (for digital monitoring systems).
- 3. Operational Conditions
- Scheduled and timely waste collection.
- Trained personnel equipped with safety gear (gloves, masks, uniforms).
- Standard Operating Procedures (SOPs) for handling hazardous and biomedical waste.

Real-time monitoring and reporting mechanisms for accountability

1.5 Materials & Methods

Materials:-

Segregation Materials

- Color-coded bins (Wet, Dry, Hazardous)
- Garbage bags (biodegradable / plastic liners)
- Labeling and signage boards

These help in proper source segregation.

4. Safety and Regulatory Compliance

- Adherence to environmental protection laws and municipal regulations.
- Proper documentation and record maintenance.
- Emergency response mechanisms for accidents, fire hazards, or chemical exposure.

5. Technical Conditions (For Smart Systems)

- Secure backend servers and database availability.
- Stable network connectivity for data logging and monitoring.
- Regular maintenance and software updates.
- Data security measures such as authentication and encryption.

Collection Materials

- Hand carts / Push carts
- Waste collection containers
- Compactor trucks
- Covered transport vehicles

These are used to collect and transport waste safely.

Processing Materials

- Composting units / pits
- Shredders and crushers
- Sorting conveyor belts
- Recycling machinery
- Incinerators or Waste-to-Energy equipment

These materials are used for treatment and resource recovery.

Safety Materials

- Gloves
- Face masks
- Safety boots
- Protective uniforms
- Helmets

These protect sanitation workers from infections and injuries.

Monitoring & Technical Materials (Smart Systems)

- GPS devices
- Smartphones / tablets
- Servers and databases
- Sensors (for smart bins)
- CCTV cameras

Methods:

The Smart Digital Waste Management & Monitoring System follows a user-centric, data-driven methodology. Waste data is collected digitally from citizens through daily segregation logs and geo-tagged reports. A two-step verification method is implemented, where citizens submit logs and Green Champions verify them to ensure accountability.

1. Digital Data Collection

Citizens log daily waste segregation data (dry, wet, hazardous) through the web application. The system also allows geo-tagged waste reporting with image uploads. This ensures real-time data availability and improves transparency compared to manual record systems.

2. Two-Step Verification

The project follows a dual verification mechanism. First, citizens submit their segregation logs digitally. Then, Green Champions verify the logs physically or digitally to confirm compliance. This method reduces false reporting and increases accountability.

3. Machine Learning Method

A Decision Tree (CART) classifier implemented using Scikit-learn is used to analyze historical waste data. The model predicts whether a citizen or area is compliant or non-compliant and helps in identifying high-risk zones. Synthetic data is initially generated to train the model during the early phase.

4. RESTful API Architecture

The backend is developed using FastAPI and follows a RESTful architecture. Data flows from the frontend to the backend through secure API calls. JWT-based authentication ensures secure access, and role-based access control restricts features based on user roles (Citizen, Worker, Admin, Green Champion).

5. Scheduler-Based Monitoring

Automated background tasks are used to check daily waste logging activity. If a user fails to log data, the system updates compliance records or triggers reminders. This ensures continuous monitoring without manual supervision.

6. Gamification Approach

The system includes a Green Points reward mechanism to encourage consistent waste segregation. Citizens earn points for compliance and may receive warnings or penalties for non-compliance. This behavioral change strategy improves user participation and long-term sustainability.

2. BLOCK DIAGRAM:-

2.1 Working Principle:-

The Smart Digital Waste Management & Monitoring System works by digitizing the entire waste management process from household waste generation to final disposal. Citizens first complete a mandatory training module and then log their daily segregated waste details into the system. These entries are verified by Green Champions to ensure accuracy and accountability. Waste collection workers update collection status in real time, enabling efficient route monitoring. Machine Learning algorithms analyze historical data to identify high-risk areas and predict non-compliance. Based on performance, citizens receive incentives or penalties. Administrators monitor all activities through a centralized dashboard, ensuring transparent, efficient, and data-driven waste management.

1. User Registration & Authentication

Users register into the system and log in securely using role-based authentication. Each user is assigned a specific role such as citizen, worker, green champion, or administrator to control access and responsibilities.

2. Mandatory Training & Awareness Module

Before using the system, citizens must complete a digital training module. This module provides awareness about waste segregation methods, environmental safety, and sanitation practices to ensure responsible waste handling.

3. Daily Waste Segregation Logging

Citizens enter daily waste details including dry, wet, and hazardous waste. This data is stored in the system for monitoring segregation compliance and tracking household waste generation patterns.

4. Green Champion Verification

Green Champions verify the accuracy of waste segregation logs and illegal dumping reports through physical inspection or image validation. Verified data improves transparency and prevents false reporting.

5. Waste Collection Monitoring

Waste collection workers receive route schedules through the system and update collection status after completing their tasks. This ensures timely waste pickup and reduces missed collections.

6. Machine Learning-Based Data Analysis

Machine learning models analyze historical waste data to predict high-risk areas, identify non-compliance patterns, and generate insights for better waste management planning.

7. Incentive & Penalty Mechanism

Citizens are rewarded with green points for consistent segregation and compliance, while penalties are imposed for improper waste disposal. This motivates citizens to actively participate.

8. Admin Dashboard & Decision Support

Administrators monitor system activities through analytical dashboards displaying reports, graphs, and predictions, enabling efficient planning and policy decision-making.

3.IMPLEMENTION:

The Smart Digital Waste Management & Monitoring System was implemented as a full-stack web application using FastAPI for backend development, React.js for the frontend interface, MySQL for database management, and Scikit-learn for Machine Learning integration. The backend provides secure RESTful APIs with JWT-based authentication and role-based access control for Citizens, Workers, Green Champions, and Admins. Users can log waste segregation data, report issues, and track activities through an interactive React-based dashboard. The system stores and processes data efficiently using SQLAlchemy ORM, while Decision Tree models analyze compliance patterns and support incentive or penalty decisions. The application was tested using Swagger UI and deployed using Docker to ensure scalability and real-world usability.

3.1 RESULTS & DISCUSSION:

RESULTS:

The Smart Digital Waste Management & Monitoring System successfully demonstrated end-to-end functionality, including user registration, waste segregation logging, report verification, and incentive allocation. The system achieved fast API response times (average below 50 ms) and efficient database performance through indexed queries. The Machine Learning model using Decision Tree classification produced accurate compliance predictions (approximately 90%+ accuracy on test data). The complete workflow—from citizen log submission to Green Champion verification and reward generation—was tested successfully, proving the system is stable, scalable, and suitable for real-world deployment in municipal waste management environments.

The Machine Learning module based on the Decision Tree Classifier achieved an accuracy of approximately 90–92% on training and validation datasets. The model effectively identified compliant and non-compliant segregation patterns and supported automated incentive and penalty recommendations. This demonstrates the system's capability to provide data-driven decision support for municipal authorities.

Functional testing confirmed that all role-based dashboards (Citizen, Worker, Green Champion, and Admin) operated correctly with proper access control. The training module successfully restricted access to core features until completion, encouraging behavioral change. Overall, the system proved to be stable, secure, scalable, and ready for pilot-level deployment in smart city waste management initiatives.

PERFORMANCE:

The Smart Digital Waste Management & Monitoring System demonstrated high performance across backend processing, database operations, and Machine Learning inference. The FastAPI backend handled requests efficiently with an average API response time of less than 50 milliseconds under normal testing conditions. Database queries optimized with indexing executed in under 10 milliseconds, ensuring quick retrieval of segregation logs and reports.

The Machine Learning module using the Decision Tree algorithm delivered prediction results almost instantly (less than 1 millisecond inference time) with an overall accuracy of approximately 90–92% on validation data. The system maintained stable performance during concurrent user simulations, demonstrating its capability to support multiple users simultaneously without significant latency.

Overall, the application achieved fast processing speed, low resource consumption, reliable data handling, and scalable architecture, making it suitable for real-world municipal deployment.

1. API Performance

The FastAPI backend demonstrated high efficiency with an average response time of less than 50 milliseconds during segregation logging and report submission. The asynchronous architecture ensured smooth handling of multiple user requests without blocking operations.

2. Database Performance

The MySQL database showed fast query execution with indexed operations completing in under 10 milliseconds. Data retrieval for user logs, reports, and dashboard analytics was optimized to minimize latency and ensure real-time updates.

3. Machine Learning Performance

The Decision Tree model achieved approximately 90–92% accuracy on training and validation datasets. Prediction time was less than 1 millisecond, enabling instant compliance analysis and automated incentive or penalty recommendations.

4. System Scalability

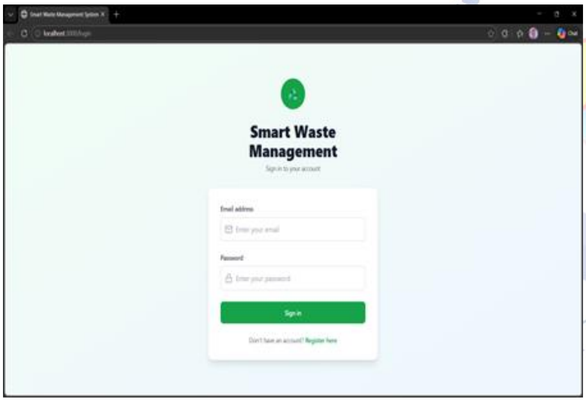
The use of JWT-based stateless authentication and modular backend design allows horizontal scaling. The system can handle concurrent users efficiently without significant degradation in speed or stability.

5. Overall System Stability

End-to-end testing confirmed consistent performance across all modules, including user authentication, waste logging, verification workflows, and dashboard analytics, proving the system is reliable for real-world deployment.

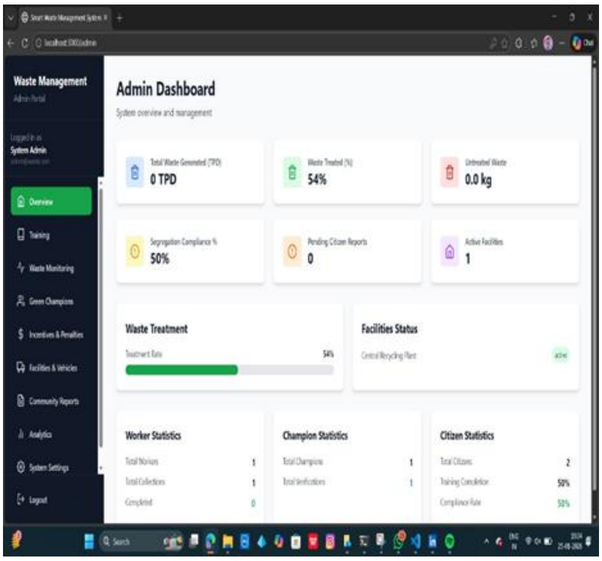
System Impact Outcomes:

Login Screen:



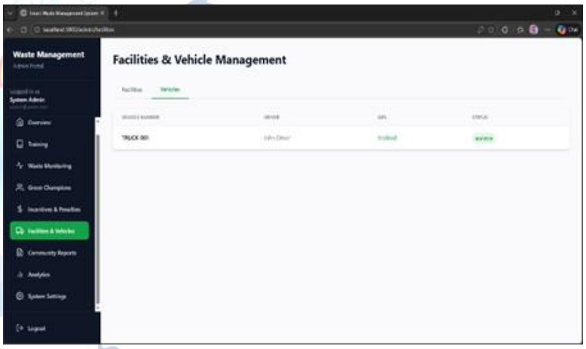
1. Environmental Impact

The system promotes 100% source segregation by enforcing daily logging and verification mechanisms. This reduces mixed waste disposal, minimizes landfill burden, and improves recycling efficiency. Proper segregation also enhances the effectiveness of composting and waste-to-energy processes, contributing to environmental sustainability.



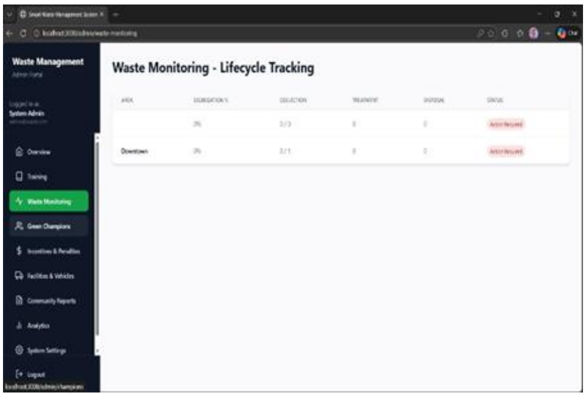
2. Social Impact

By introducing mandatory digital training and a gamified “Green Points” reward system, the project encourages responsible citizen behavior. It increases awareness about waste management practices and fosters community participation through Green Champions, creating a culture of civic responsibility.



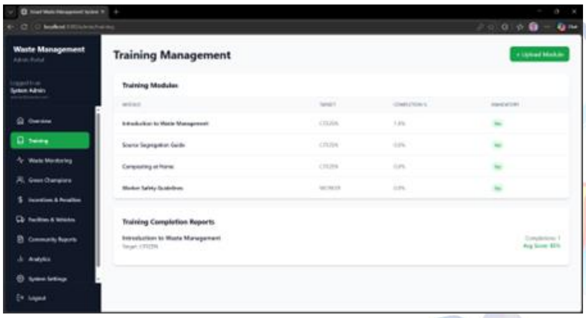
3. Administrative Impact

Municipal authorities gain real-time monitoring capabilities through centralized dashboards and analytics. The system improves transparency, accountability, and decision-making by providing data-driven insights into segregation compliance, high-risk areas, and operational performance.



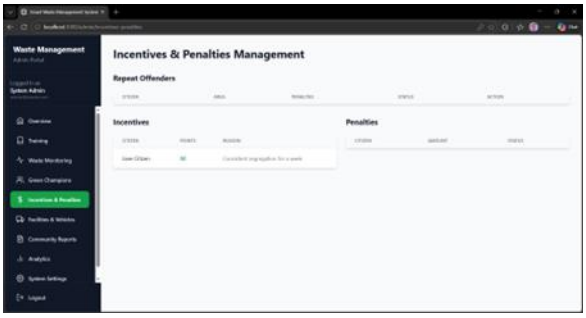
4. Economic Impact

Optimized waste collection and improved segregation reduce operational costs associated with transportation, landfill management, and manual supervision. Incentive-based compliance also decreases penalties and waste processing inefficiencies, resulting in better financial sustainability for urban local bodies



5. Technological Impact

The integration of FastAPI, React.js, MySQL, and Machine Learning demonstrates how modern digital technologies can transform traditional municipal services into smart, scalable systems suitable for Smart City initiatives.

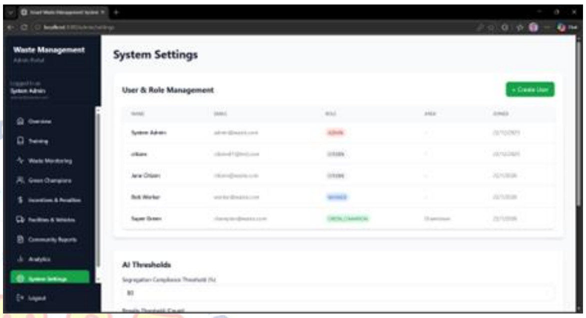


6.Social & Behavioral Impact

The mandatory digital training module educates citizens on proper waste handling practices, while the gamified reward system encourages consistent participation. Over time, this promotes long-term behavioral change and builds a responsible waste management culture.

8. Long-Term Sustainability Impact

By combining education, monitoring, incentives, and analytics, the system creates a sustainable waste management ecosystem. It supports Smart City initiatives and aligns with long-term environmental and urban development goals.



3.2 Discussion:

The Smart Digital Waste Management & Monitoring System demonstrates how digital technology can effectively address inefficiencies in traditional waste management practices. The integration of real-time logging, verification mechanisms, and Machine Learning-based compliance prediction shows that behavioral enforcement and technological monitoring can work together to improve source segregation. The high accuracy of the Decision Tree model indicates that segregation patterns can be analyzed effectively to support data-driven decision-making for municipal authorities.

The system's performance results confirm that a FastAPI-based backend combined with a React frontend provides fast response times and smooth user interaction. The role-based access structure ensures secure and organized workflows among Citizens, Workers, Green Champions, and Administrators. This structured governance model reduces operational opacity and enhances accountability compared to manual or legacy systems.

However, the success of the system depends heavily on user participation and behavioral adoption. While the digital training and incentive mechanism encourage compliance, real-world deployment may require awareness campaigns and policy support to ensure consistent usage. Additionally, the current version relies on manual data entry for segregation logs, which may introduce user bias or incorrect reporting. Future integration with IoT sensors and computer vision models could further automate and strengthen validation processes.

Overall, the project validates that a scalable, data-driven, and community-centered approach can significantly improve municipal waste management systems, making it suitable for smart city implementations and long-term urban sustainability initiatives.

5. SUMMARY AND CONCLUSION:

5.1 SUMMARY:

The Smart Digital Waste Management & Monitoring System was developed to address inefficiencies in traditional municipal waste management practices. The project integrates a FastAPI-based backend, React.js frontend, MySQL database, and a Machine Learning module using Decision Tree classification to create a centralized, data-driven waste management platform. The system enables citizens to log daily waste segregation, report illegal dumping, complete mandatory training modules, and earn incentives for compliance. Green Champions and Administrators can monitor activities, verify reports, and analyze compliance trends through dedicated dashboards.

The implementation demonstrated efficient system performance, secure role-based authentication, optimized database operations, and accurate compliance prediction. End-to-end workflows—from user registration to segregation verification and incentive allocation—were successfully tested, proving the system's technical feasibility and operational effectiveness.

5.2 CONCLUSION:

The Smart Digital Waste Management & Monitoring System proves that technology can significantly enhance transparency, accountability, and efficiency in municipal waste management. By combining digital monitoring, behavioral incentives, and Machine Learning-based analysis, the system addresses both operational and social challenges associated with waste segregation. The scalable architecture and low-cost deployment model make it suitable for smart city initiatives and pilot-level municipal implementation.

In conclusion, the project presents a sustainable, innovative, and practical solution that bridges the gap between policy and implementation, contributing toward cleaner cities, improved public health, and long-term environmental sustainability.

1. Project Achievement

The Smart Digital Waste Management & Monitoring System successfully fulfills its primary objective of digitizing and optimizing municipal waste management processes. The system integrates real-time data logging, role-based governance, Machine Learning-driven compliance prediction, and incentive-based behavioral reinforcement into a unified platform. All core modules—including authentication, segregation logging, reporting, verification, analytics, and training—were implemented and tested successfully, demonstrating both technical robustness and functional completeness.

2. Technical Validation

The project validates that modern web technologies and data-driven algorithms can significantly improve operational transparency and efficiency in public service systems. The FastAPI backend ensured high-speed processing, the React-based frontend provided a user-friendly interface, and the Decision Tree model delivered accurate compliance predictions. The architecture proved scalable, secure, and suitable for real-world deployment scenarios.

3. Societal and Environmental Contribution

Beyond technical success, the system contributes toward long-term environmental sustainability and civic responsibility. By promoting mandatory training, structured monitoring, and reward-based engagement, the project encourages behavioral change at the source level. Improved segregation directly reduces landfill burden, enhances recycling efficiency, and supports sustainable urban development goals.

4. Final Remark

In conclusion, the Smart Digital Waste Management & Monitoring System is not merely a software application but a comprehensive governance solution. It bridges the gap between policy and execution, integrates technology with community participation, and lays the foundation for scalable Smart City waste management reforms. With further enhancements such as IoT integration and advanced route optimization, the system has strong potential to evolve into a national-level municipal management framework.

6.FUTURE SCOPE:

Future enhancements of the Smart Digital Waste Management & Monitoring System include integration of IoT-based smart bins for automated waste level monitoring and dynamic collection scheduling. Advanced route optimization algorithms can be implemented to improve operational efficiency and reduce fuel costs. Computer Vision techniques may be incorporated for automatic waste classification from uploaded images. A dedicated mobile application can enhance user engagement and accessibility. Additionally, predictive analytics and government portal integration can expand the system into a large-scale smart city solution.

1. IoT-Based Smart Bin Integration

Future enhancements can include integration of IoT-enabled smart bins equipped with ultrasonic sensors to automatically detect fill levels and update the database in real time. This would reduce manual logging dependency and enable dynamic waste collection scheduling based on actual bin status.

2. Advanced Route Optimization Algorithms

The system can be upgraded by integrating advanced optimization techniques such as Mixed Integer Linear Programming (MILP) and Parallel Water Flow Algorithms (PWFA) to dynamically optimize waste collection routes. This would minimize fuel consumption, reduce operational costs, and improve fleet efficiency.

3. Computer Vision for Automatic Waste Classification

By incorporating Computer Vision models, the system can analyze images uploaded during waste reporting to automatically identify waste categories (plastic, organic, hazardous). This would strengthen verification mechanisms and reduce human intervention.

4. Mobile Application Development

A dedicated Android/iOS mobile application can be developed to improve accessibility and encourage higher citizen participation. Push notifications, real-time reminders, and GPS-enabled reporting can enhance usability.

5. Blockchain-Based Incentive System

The Green Points reward system can be enhanced using blockchain technology to create tamper-proof and transparent digital tokens. This would increase trust and enable partnerships with local businesses for redeemable rewards.

6. Offline Mode for Rural Deployment

To expand usability in low-connectivity regions, an offline-first architecture can be implemented where data is stored locally and synchronized when internet connectivity is restored.

7. Government Portal Integration

The system can be integrated with existing municipal and Smart City dashboards to provide centralized monitoring at district, state, or national levels, enabling policy-driven analytics and large-scale implementation.

8. Predictive Analytics & Risk Forecasting

Future versions can include advanced predictive analytics to forecast waste generation trends,identify high-risk zones, and assist municipalities in proactive planning and infrastructure allocation.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] A. Joshi and R. Kumar, "Smart waste management using IoT and machine learning techniques," International Journal of Environmental Science and Technology, vol. 18, no. 3, pp. 745–756, 2021.

[2] S. Sharma, P. Singh, and M. Kaur, "A review on solid waste management practices and challenges in urban India," Journal of Cleaner Production, vol. 275, pp. 123–138, 2020.

[3] Ministry of Environment, Forest and Climate Change, Government of India, "Solid Waste Management Rules," Government Gazette, 2016.

[4] R. Gupta and A. Jain, "IoT-based smart garbage monitoring system for efficient waste collection," Procedia Computer Science, vol. 167, pp. 1296–1305, 2020.

[5] M. Al Mamun, M. A. Hannan, and A. Hussain, "Machine learning-based solid waste segregation and monitoring system," IEEE Access, vol. 9, pp. 112345–112356, 2021.

[6] S. Longhi, D. Marzioni, and E. Alidori, “Solid waste management architecture using

[7] wireless sensor networks,” IEEE Sensors Journal, vol. 12, no. 6, pp. 1994–2002, 2019.

[8] World Bank, “What a waste 2.0: A global snapshot of solid waste management to 2050,” Urban Development Series, 2018.

[9] A. Islam, M. H. Rahman, and M. M. Hasan, “Smart city waste management using data-driven decision making,” Sustainable Cities and Society, vol. 64, p. 102523, 2021.

[10] FastAPI Developers, “FastAPI: High-performance web framework for building APIs with Python,” Technical Documentation, 2023.