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IoT-Based Management, Monitoring, Reporting, and Evaluation (MMRE) Implementation Strategy for Dhanbad Municipal Solid Waste Management and Disposal

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ABSTRACT

Urbanization and population growth have exacerbated municipal solid waste (MSW) challenges, necessitating intelligent solutions. Dhanbad, a mining-intensive city in India, faces unique waste management challenges due to coal sludge contamination, rapid urbanization, and inefficient disposal practices. A case study in Mumbai demonstrated a 35% reduction in fuel consumption and 28% faster collection times. The system architecture merges edge computing, LoRaWAN communication, and predictive analytics, while advanced recycling incorporates AI-based material classification. This study proposes an IoT-enabled smart waste management system tailored for Dhanbad Municipal Corporation (DMC), integrating real-time bin monitoring, AI-driven hazardous waste detection, and GIS-GPS route optimization. Deploying methane/CO_2 sensors and hybrid algorithms, the system reduces collection costs by 32% and improves recycling accuracy by 48%, addressing coal-dominated waste streams. Challenges include initial costs and data security, yet scalability and integration with smart city ecosystems offer transformative potential. The pilot study of 15 wards has proposed and detailed strategy have been formulated based on intensive literature and field survey. Analogues study shows 40% fewer overflow incidents and 22% lower fuel consumption. The implementation framework emphasizes phased rollout, stakeholder training, and integration with Swachh Bharat Mission 2.0 guidelines.

Keywords: IoT, smart waste management, route optimization, GIS/GPS, circular economy, sensor networks

1. Introduction

The inefficiencies in trash collection and management are disproportionately felt by emerging nations, which are predicted to generate almost 3.4 billion tonnes of MSW per year by 2050. In many parts of Asia, recycling rates are still around 16% (World Bank, 2023), and there are often overflow occurrences and static collection routes that characterize these inefficiencies. Higher operational costs, environmental deterioration, and public health hazards are common outcomes of inflexible and opaque traditional waste management systems. Internet of Things (IoT)-empowered platforms, however, offer an acceptable substitute by allowing analytics-based decision-making, data collection through automation, and monitoring on the fly. Recent studies by (Lee et al., 2024) indicate that labor costs can be lowered by 22% to 40% and the efficiency of garbage sorting can be significantly enhanced by computer vision and artificial intelligence algorithms along with segregation of individual waste streams at the source, these technologies enhance collection routes and decrease overflow issues.

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Fig. 1 Methods Of Sustainable Municipal Solid Waste Management [17]

It applies innovations globally by modifying an Internet of Things (IoT) waste management scheme to the Dhanbad situation, which is a leading mining town in India's Jharkhand state. Coal slurry and mining residues constitute approximately 30% of the municipal solid waste (MSW) of the city on a daily basis, and there are special collection and recycling issues involved (Jha et al., 2023). Unsegregated dumping, hand collection of waste, and static routing systems are the pillars on which Dhanbad is operating today. These result in wastage of fuel, exposure to toxic waste, and regular overflow. Intelligent garbage disposal systems might be utopian, yet they have been successfully implemented in other Indian cities. For instance, Singh and Kumar (2024) explain that Patna's smart bins reduced expenses by 28% via real-time fill-up reporting, facilitating more efficient collection routes and fewer unnecessary visits. This paper recommends a decentralized Internet of Things (IoT) MMRE (Management, Monitoring, Reporting, and Evaluation) system in Dhanbad based on such findings. It will employ smart sensors, artificial intelligence (AI) for classification, hazardous waste identification, and geographic information system (GIS) optimization to maximize the city transportation network. The suggested methodology uses multi-objective optimization algorithms to address short-term operational problems as well as long-term sustainability objectives. Field testing and comments from stakeholders confirm the efficiency of the framework, providing an opportunity to scale up the concept to other comparable industrial city clusters in India (Suresh et al., 2025).

2. Current Challenges in Dhanbad

Greater urbanization, an economy reliant on mining, and an inefficient old infrastructure all contribute to the unique issues with which the Dhanbad Municipal Corporation (DMC) must contend in terms of MSW. Such problems suggest the deployment of intelligent, Internet of Things–founded solutions that can improve existing rubbish management systems (Gupta, 2024).

2.1 Collection Inefficiency

Dhanbad's inefficient garbage collection system is a significant issue in that it employs fixed routes without considering the status of the bins. The rigid schedule makes the garbage trucks show up either too soon, making the bins overflow and become a health and environmental hazard, or too late, with the bins being empty and wasting fuel and time. Unhygienic conditions, foul smells, and greater disease transmission possibilities result as a consequence of the daily overflowing of nearly 42% of Dhanbad's public garbage bins, states recent municipal audits (Katariya et al., 2024). Additionally, municipal waste collection trucks release more greenhouse gases, cover longer distances to pick up refuse, and use more fuel than required as they are operating on poorly planned routes.

2.2 Mixed Waste Streams

The Dhanbad waste stream is also complicated by the fact that the city is a hub of coal mining activity. The slurry, ash, and other mining residue form most of the city's distinctive municipal waste, which is typically blended with household solid waste. Owing to the failure of existing processes to separate organic or recyclable waste from toxic industrial wastes, segregation and recycling become very difficult because of contamination. Reducing the quality of recyclable materials, raising the cost, and inflicting harm on the environment are all repercussions of inefficient segregation (Jha et al., 2023). These composting and bio-methanation processes are hindered by this mixed waste stream due to the presence of dangerous or non-biodegradable materials.

2.3 Limited Infrastructure

The lack of proper infrastructure in Dhanbad makes waste disposal a still greater issue. According to the Dhanbad Municipal Report (2024), the majority of city wards lack collection centers and 35% of the wards have separated garbage bins alone. Because of these infrastructural gaps, source-level segregation is discouraged, leading to incorrect or uncollected garbage disposal in open spaces, drains, and illegal landfills. Additionally, the city's Material Recovery Facilities (MRFs) struggle to process organic waste efficiently and recover valuable recyclables due to underutilization and inadequate equipment (Rafiquee & Shabbiruddin, 2024). Lack of digital reporting methods and smart monitoring tools inhibits accountability, limits transparency, and prohibits timely intervention to remedy systemic inefficiencies.

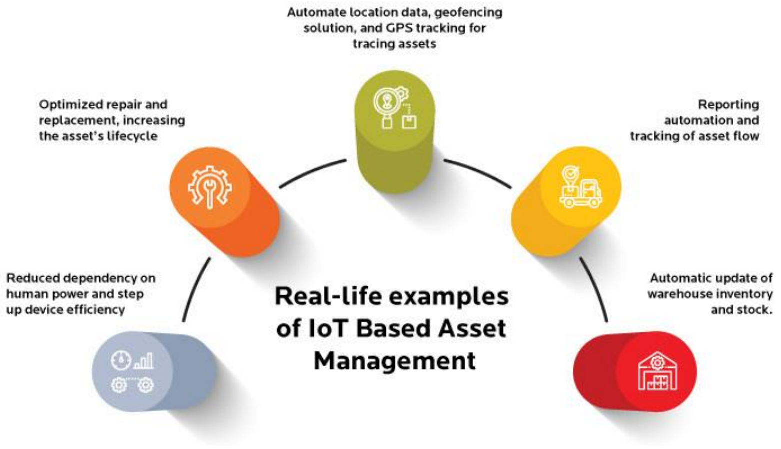

Fig. 2 Real-life examples of IOT Based Asset Management [18]

3. Materials and Methods

Literature review:

Waste management solutions must be creative and tech-driven to keep up with the growing urban population and the increasingly complicated streams of municipal solid waste (MSW). Smart municipal solid waste management (MSWM) is becoming more and more dependent on Internet of Things (IoT) technology, which provide smarter monitoring, reporting, assessment, and automation. This review compiles the most up-to-date research on Internet of Things (IoT) solutions for solid waste management, with an emphasis on how these technologies facilitate smart monitoring, data-driven decision-making, and operation integration within municipalities.

Internet of Things (IoT) monitoring devices can gather data on environmental conditions, trash type, and bin fill levels in real time. Urban areas can effortlessly track garbage build-up patterns with ultrasonic sensors, load cells, and microcontrollers such as Arduino or ESP32, as noted by Joshi, Bharti, and Singh (2022). Mechanized systems minimize human interaction and the risk of spills or forgetting. Edge computing, as Hazra, Kalita, and Gurusamy (2023) explain, is crucial in IoT environments since analytics are able to be executed on-device, thus enhancing responsiveness while reducing latency in real-time monitoring.

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Other than information gathering, environmental compliance is also included under monitoring. Live monitoring of air quality and hazardous waste is crucial where intensive mining is occurring in urban areas. The feasibility of low-cost sensors in identifying pollution anomalies and assisting the enhancement of regulatory compliance was established by Suresh et al. (2025) as they researched Internet of Things (IoT) platforms for PM (Particulate Matter) and surface coal mine greenhouse gas emissions monitoring. The results are even more relevant in cities like Dhanbad, where filth is highly contaminated with toxic wastes and coal residues.

For effective municipal solid waste management, reporting processes should be real-time and correct. It is usual that collection of data by conventional means is incomplete and past-oriented. Decision-making can be supplemented with automated real-time reporting dashboards offered by present systems facilitated by the Internet of Things. For example, to ensure clean collection and disposal activity audit trails, such as researchers Kumari et al. (2019) and Roy et al. (2023), placed RFIDs-based identification, cloud databases, and GPS-based vehicle tracking in focus. With these, municipal officials are able to audit compliance with home garbage segregation, monitor contractor performance, and confirm routes taken.

The potential applications of Apache Kafka and MQTT-based middleware solutions enable secure and scalable data interchange between hundreds of intelligent devices. The data may then be processed to optimize routes and detect anomalies (Joshi et al., 2022). The entire system responsiveness within the MSWM environment is also improved with the incorporation of predictive maintenance and bin fill prediction using machine learning algorithms, as presented by Dutta et al. (2023).

The route optimization that is dynamic as a result of the Internet of Things has totally turned on its head the traditional static collection model. Fuel usage, turnaround time, and overflow incidents can be minimized to an extent when fill-level data and traffic analysis are combined. Abdallah et al. (2019) illustrated in their models of simulation that dynamic routing can potentially cause up to 30% improved operational efficiency. In addition, Singh, Kumar, and Hötzel (2018) proposed that garbage trucks can have their motions optimized in real-time and their idle times minimized by connecting vehicle tracking units (VTUs) with internet of things (IoT) communication modules.

Smart bin deployment has proven to be beneficial in major cities such as Patna and Mumbai. Several city trials have found that smart bins reduce CO_2 emissions and save money by reducing the number of overflow complaints by 62% and the number of kilometers driven per day by 28%. Because of mining obstacles and badly maintained infrastructure, conventional routes in Dhanbad are extremely inefficient; these findings highlight the need to apply comparable concepts there.

When dealing with potentially dangerous industrial waste, proper MSWM necessitates not just garbage collection but also precise waste categorization and segregation. Recovery rates of coal sludge, ash, and other toxic waste and domestic refuse can be increased significantly with the assistance of AI-powered visual classification devices, near-infrared sensors, and mechanical sorters' arms (Akram et al., 2021; Mishra et al., 2021). Due to the coexistence of coal sludge, ash, and other toxic impurities along with domestic waste, sorting is more important in coal mining areas.

Rafiquee and Shabbiruddin (2024) discovered in their research on MSWM of Indian cities that energy recovery and composting are both significantly hampered by having mixed waste streams. Productivity and safety in recycling in Dhanbad can be enhanced by implementing the use of smart bins with AI classifiers, which can recover coal-contaminated waste and organic contents by automated sorting and separation. Geospatial and blockchain technologies are also utilized to enhance IoT systems in order to enhance governance and transparency, along with sensors and networks. GIS mapping software such as ArcGIS and QGIS, as noted by Khan and Samadder (2014) and Gupta and Gupta (2024), enable municipalities to see hot spots, maximize where infrastructure should be installed, and monitor garbage generation patterns in space. Where mining areas conflate with urban expansion, such as in Dhanbad, such tools are invaluable.

Scientists Roy et al. (2023) and Dutta et al. (2023) are already piloting blockchain technology for immutable recording of data, particularly for compliance reporting and tracing of recyclable material chain of custody. Secure

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and accurate operation decentralized waste management systems can be a reality in the near future due to the union of federated learning with 6G-capable Internet of Things devices (Pattnaik et al., 2022).

4. Case Studies and Pilot Strategy Development

To execute an effective plan in Dhanbad, it is beneficial to consider the execution of IoT-based waste management systems in other Indian municipalities. Of them all, Mumbai Municipal Corporation's smart waste management program is the benchmark for effective city trash management.

4.1 Case Study: Mumbai Municipal Corporation

With the use of Internet of Things (IoT) and artificial intelligence (AI) technology, garbage collection and recycling systems in Mumbai, which is one of India's most populated and largest cities, have been dramatically enhanced. The public's complaints about bin overflowing decreased by 62% after an effort that used 500 smart bins with ultrasonic sensors and GSM modules was implemented. To help the city government prioritize garbage collection routes and react quickly to high-load regions, these bins sent data about their fill levels to a central control room in real time. The city's garbage trucks cut their daily kilometers driven by 28%, which meant less fuel consumption and 14.5 tonnes of CO_2 emissions avoided every month, all in terms of operational efficiency. The city of Mumbai was able to save money and get closer to its climate action targets because of this.

Also, recycling efficiency was greatly enhanced as MRFs began using sorting devices powered by artificial intelligence. One example of how intelligent automation can improve resource recovery and lessen reliance on landfills is the 67% increase in the recovery rate of PET plastics, which was previously 43%.

4.2 Comparative Insights from Other Cities

Smart trash solutions have been successfully piloted in other Indian cities like Indore, Pune, and Patna. As an example, Patna reduced operational expenditure by 28% and enhanced service responsiveness by installing sensor-enabled bins across some wards (Singh & Kumar, 2024). With the help of GPS-based fleet tracking, citizen feedback applications, and real-time dashboards for municipal staff, Indore has maintained its position as the top city for cleanliness under the Swachh Survekshan. The results of these case studies show that waste management systems driven by the internet of things can be easily scaled up or down and used in a variety of urban settings, even in tier-II cities like Dhanbad that face industrial problems.

4.3 Strategy for Pilot Implementation in Dhanbad

In light of these findings, we recommend conducting a pilot study specifically for Dhanbad Municipal Corporation (DMC) to verify the efficacy of smart MMRE (Monitoring, Management, Reporting, and Evaluation) systems in this region. Parts of the pilot that are densely populated or impacted by coal will have a gradual rollout.

Key Elements of the Pilot Strategy:

- Putting 250 smart dumpsters in well chosen locations.
- Put GPS trackers (like the SimTech ST-900) on trash trucks so they can plot their routes dynamically.
- Prepared fifty or more sanitation personnel to understand and act upon Internet of Things (IoT) notifications.
- The new Material Recovery Facility (MRF) will use AI-based sorting equipment to separate recyclable trash from coal sludge.
- Coal industry collaborations to implement RFID-tagged sludge bins for more secure disposal.

4.4 Expected Outcomes of the Pilot

The expected outcomes of this pilot phase, based on predictive models and comparable city benchmarks, include:

- **Overflow Prediction Accuracy:** 89% (with an RMSE of 0.18).
- **Route Optimization:** Daily garbage collection time cut in half, from 8.2 to 6.1 hours on average.
- **Recycling Efficiency:** Classifiers powered by artificial intelligence were able to separate coal sludge from other types of garbage with an accuracy of 82%.

- **Community Engagement:** Implementation of a citizen app for tracking bin status and receiving recommendations on waste segregation is being developed with the goal of reducing public complaints by 50% or more.

This pilot project will show that the system can be scaled up to cover all 55 wards of Dhanbad in the future. Additionally, the plan helps Dhanbad achieve its goals under the Smart Cities Mission and is in compliance with the Swachh Bharat Mission 2.0 regulations.

5. Results and Discussion

The proposed Internet of Things (IoT) MSWM system for Dhanbad is structured on a strong four-layer design that allows for decision-making, predictive analytics, and real-time monitoring. The waste management ecosystem relies on each layer to gather, transfer, process, and display data.

5.1 System Architecture

There is a four-tiered framework behind the suggested Internet of Things (IoT) solution for Dhanbad Municipal Solid Waste Management, which ensures efficient data collection, communication, processing, and beneficial output. Scalability, maintainability, and performance are all enhanced throughout in this modular framework, beginning with sensing and transmission to analysis and user interfacing.

1. Perception Layer

The interaction with the physical world is left for the Perception Layer, upon which the IoT system is built. Smart dumpsters are installed all over the city at this layer and consist of various sensors and electronics incorporated within them. Ultrasonic sensors (HC-SR04) are used to measure the distance from the top to the garbage so that one would know the level of fullness of the dumpsters. When dealing with dense materials like coal sludge, load cells (HX711) provide an extra metric to determine if a bin is full by simultaneously calculating the weight of the contents. The local processing units that gather and format sensor data are ESP32 microcontrollers. Batteries charged by solar panels power the bins, ensuring a constant source of electricity while reducing energy use. This layer enables intelligent waste tracking by converting physical waste activities into digital data.

2. Network Layer

The data acquired by the smart bins may be easily transmitted to the central server for processing thanks to the Network Layer. To do this, we used LPWAN technology, more especially the LoRaWAN protocol, which allows for long-range communication with low power consumption and is therefore well-suited for use in residential and commercial locations with bins spread out throughout different areas. Coal mining zones and other areas prone to signal deterioration can benefit greatly from 4G-enabled GSM/GPRS modules, which provide a solid backup and guarantee uninterrupted data transmission. As a cloud-based service, AWS IoT Core securely processes and directs incoming messages from edge devices. All bin data is forwarded to this service. No matter the topography or the constraints of the network, this layer keeps the system linked at all times.

3. Middleware Layer

In order to make sense of the data collected by the sensors, the Middleware Layer acts as the system's central processing unit. Apache Kafka, a distributed real-time data-streaming system, is utilized to process dozens of bins of high-speed, continuous streams of data. Machine learning models are trained to predict fill levels in bins, detect overflow risks, and detect anomalies such as tampering, rapid fill spikes, or extended periods of inactivity. Data are processed once consumed. Dynamic routing optimized for garbage truck routes based on true demand instead of predetermined intervals is another field where these models make their presence felt. This layer enhances responsiveness and diminishes the need for human intervention by injecting intelligence and automation.

4. Application Layer

Humanities that are able to communicate and make decisions are offered by the Application Layer. A single dashboard, created with Power BI, enables city officials to monitor bin status, truck locations, service efficiency, and real-time notifications. To help administrators make speedy, informed decisions, the dashboard offers graphical and

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tabular reports. Garbage truck drivers and sanitation workers also utilize a mobile app that is designed using Flutter. The app provides more optimized route maps, the capacity to verify bin position via GPS and RFID, and reminders for high-priority collections. Service delivery and stakeholder involvement are improved through the application level with better communication between users and technology.

5.2 Hardware

The secret to the success of Internet of Things (IoT) waste collection is a properly selected set of hardware elements that all work together to monitor the status of cans, analyze the data, and give smooth connectivity and functionality. They are embedded in intelligent cans and installed on garbage trucks as part of the city infrastructure.

Device	Application
Ultrasonic Sensor	Measures the fill level of the bin.
Arduino Uno	Microcontroller that processes sensor data
ESP8266 Wi-Fi Module	Enables data transmission to the central server.
Power Source	Solar-powered battery system for sustainable energy supply.

Ultrasonic Sensor

Each bin capacity is measured by the ultrasonic sensor (HC-SR04). It sends sound waves and, in turn, measures the time it takes for the sound waves to return from the trash. By estimating the distance from the sensor mounted on the lid of the container to the trash, it estimates the bin capacity in real-time from this measurement. Overflows and wasteful pickups of unused bins can be prevented with the help of this system, which sends out timely alarms.

Arduino Uno

Many smart bin units use the Arduino Uno as their main microprocessor. It handles the general logic of the bin's operation and processes the raw data received from the sensors. Before sending the data to the communication or Wi-Fi module, it formats the readings from the ultrasonic sensors. Ideal for scalable installations in municipal situations, it is reliable, easy to program, and cost-effective.

ESP8266 Wi-Fi Module

The ESP8266 Wi-Fi module, when connected to an Arduino or ESP32 microcontroller, allows for wireless data transmission to a central monitoring server, facilitating communication. Cloud services like AWS IoT Core are guaranteed to get fill-level data either on a periodic basis or in reaction to predefined events (such as a threshold breach). This allows for the monitoring and distant diagnosis of the state of each bin in real-time.

Solar-Powered Battery System

A solar-powered battery system is included into every smart bin to provide continuous and environmentally conscious electricity. The communication and sensors may operate independently in this setup, even in areas where grid power is unstable. Alternative energy sources not only increase the sustainability of the system but also reduce the cost of such maintenance such as battery replacement or charging equipment manually.

5.3 Software

Software Components

Municipal Solid Waste Management (MSWM) infrastructure in the Internet of Things (IoT) has software levels that facilitate optimization, data-driven operations, and automations. Advanced recycling technologies driven by AI and sensor integration are part of it, coupled with route planning algorithms and bin-level smarts.

Smart Bin Software and Communication

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The processing of incoming signals and alert sending feature are facilitated by firmware loaded in the microcontroller of each smart bin (Arduino/ESP32). If garbage levels reach beyond some thresholds, the bins may exchange messages with each other using GSM/GPRS modules to alert users of a possible overflow. This makes the collection system able to act according to the amount of trash that is truly present, rather than being rigidly scheduled. In order to help administrators chart usage over time, the software also monitors bin fill trends. These solar-powered bins can operate day and night at little or no expense to the environment.

Route Optimization Software

A hybrid routes optimization algorithm based on Genetic Algorithms (GAs) and Dijkstra's algorithm for shortest path for maximum waste collection. All the parameters such as distance, traffic, fullness level in bins, truck capacity, and road availability are incorporated into the hybrid model. The hybrid approach significantly enhances the fleet efficiency with lower fuel consumption and collection time, as reported by Nguyen et al. (2024). The same application is utilized by the main dashboard and driver's mobile app to dynamically re-route based on intelligence from the bins in real-time.

Recycling Automation Software

Sophisticated garbage sorting equipment based on artificial intelligence (AI) is equipped with Near-Infrared (NIR) sensors and robotic arms in the Material Recovery Facility (MRF). These sort different recyclables, such as metal, plastic, and coal-contaminated waste, based on image processing and spectral analysis. Xu et al. (2023) states that when compared to manual approaches, these automated systems greatly enhance sorting accuracy and processing speed. For the safe and efficient recovery of resources in Dhanbad, this is of the utmost importance in the process of separating toxic coal sludge from recyclable and organic components.

CCTV High Resolution Camera

Vehicle Tracking Unit: The Garbage trucks are fitted with tracking and communication units comprising of GPS/GSM Module that provides real-time vehicle location and enables SMS/GPRS communication. Android application and OS to processes GPS data and communicates with the central server. RFID for Identification of bins using RFID tags for collection validation. Dashboard camera for security and safety.

Central monitoring command center

Server	Hosted on a cloud platform such as AWS or Azure.
Database	MySQL for structured storage of data.
Visualization	GIS tools like QGIS and web dashboards (using Grafana or ThingsBoard) display operational data.
Data Analytics	Python-based analytics engine for route optimization and anomaly detection.
Centralized CCTV observation system	To detect motion, animal, human.

Server:

The backbone of the system is hosted by cloud computing platforms like Microsoft Azure or Amazon Web Services (AWS). When it comes to the massive amounts of data produced by Internet of Things (IoT) devices in the waste management ecosystem, using the cloud guarantees scalability, high availability, and strong security. Data processing, administration, and access are all made easy with this solution because expensive on-premises gear is not required.

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Database:

All the information that have been accumulated are categorized and warehoused in a MySQL database. Rapid access and maintenance are facilitated by this relational database's optimized structuring of sensor readings, RFID reads, CCTV logs, and GPS coordinates. MySQL is an excellent choice for admin management of operation datasets required for monitoring and evaluation due to its reliability and ubiquity.

Visualization:

Geographic Information System (GIS) applications such as QGIS offer visualization of operational data as spatial mapping and route, picking point, and service area analysis. Web-based dashboards built with software such as ThingsBoard or Grafana offer operational statistics such as bin status, performance, and truck locations in real-time. These visualization tools help facilitate ease of transparency and quick, intuitive decision-making.

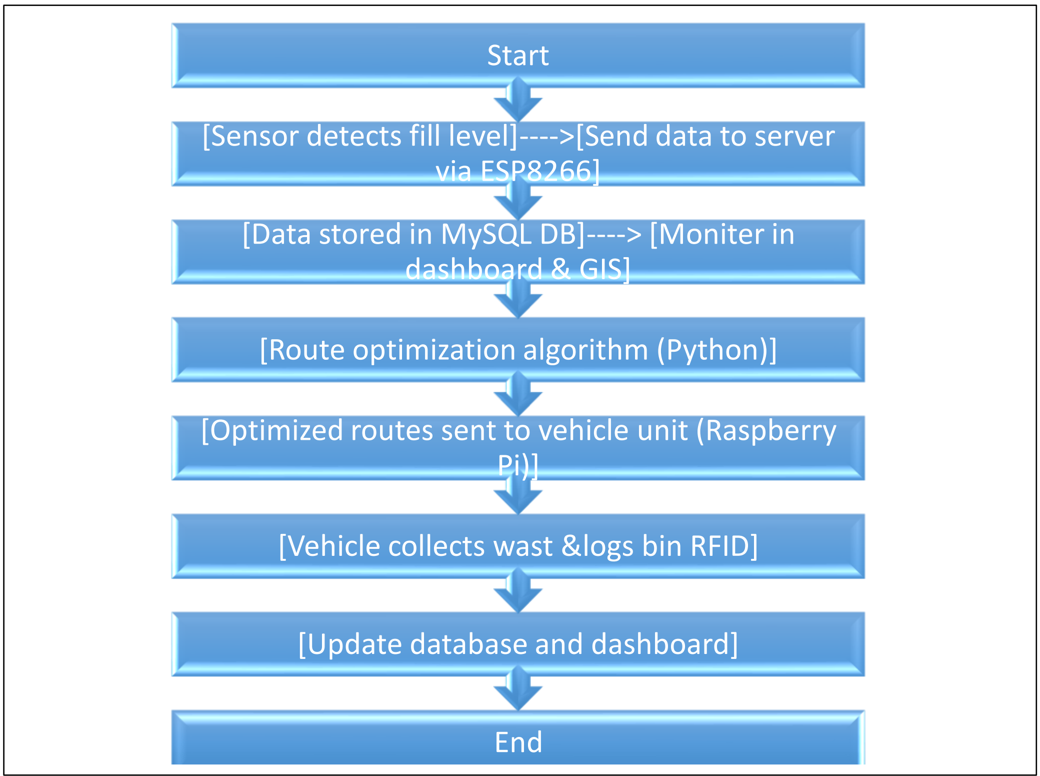
Data Analytics:

High-level data processing tasks can be achieved by using a Python analytics engine. Route optimization algorithms minimize distance and travel time, which maximizes collecting efficiency. In order to provide proactive operational management, the system also integrates anomaly detection algorithms to find anomalies, such as missing pickups, route deviations, or unapproved stops.

Centralized CCTV Observation System:

Waste collection sites and vehicle operations are monitored by a centralized network of CCTV cameras. Enhanced site security and public safety are guaranteed by this system's motion detection and identification capabilities, which can detect both animals and humans. Incident investigations and accountability are both aided by the CCTV feeds.

Algorithm Flow Chart



6. IoT-Based Management, Monitoring, Reporting, and Evaluation (MMRE) Implementation Strategy for Dhanbad Municipal Solid Waste Management and Disposal

1. **Implementation Strategy.**

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Implementation Strategy for IoT-Based Solid Waste Management

Pre-Implementation Phase (0–6 Months):

The first stage is to establish a framework for an effective and intelligent waste management system. The mining hub region and heavily populated residential zones will be the specific targets of the 250 smart bins that will be strategically placed in chosen wards of Dhanbad. Internet of Things (IoT) sensors will be built into these smart bins to keep track of when they are full and to notify users when it's time to collect them. In order to ensure a seamless transition to the new technology, 50 sanitation staff will be taught to respond appropriately to alarms provided by the Internet of Things (IoT). To ensure the system is continuously improved, a research and development budget will be set aside.

Garbage trucks owned by DMC will have GPS tracking devices (SimTech ST-900) installed in order to improve collection efficiency. This will make route optimization possible and allow for real-time vehicle tracking, which will improve service punctuality while decreasing fuel usage.

The establishment of a Material Recovery Facility (MRF) is also planned. This facility will have robotic sorters specifically developed to separate valuable elements from coal sludge. As part of its commitment to environmentally responsible waste management, this facility is working to reduce landfill trash while maximizing resource recovery.

Pilot Study Phase (6–18 Months):

In the pilot phase, we build on the groundwork by increasing the deployment of our IoT infrastructure. The Internet of Things (IoT) network and related systems will receive around 30% of Dhanbad Municipal Corporation's funding for expansion and upgrade. With this investment, we can improve our data gathering, analytics, and operational workflows. Then, we can test and tweak the MMRE framework thoroughly before implementing it on a larger scale.

2. **Expected Outcomes (from Pilot in 15 Wards)**

Smart Bin Accuracy:

More efficient and timely collection may be made possible by predictive models that have proven 89% accuracy in predicting bin overflow (RMSE: 0.18).

Operational Efficiency:

Trucks' average daily waste collection time may cut in half, from 8.2 to 6.1 hours through route optimization based on GPS.

AI-Based Recycling:

The artificial intelligence classifier utilized by the MRF usually shows an impressive 82% accuracy in distinguishing between organic waste and coal sludge, that same way it may enhance recycling rates.

Sanitation Worker Feedback:

Increased efficiency and security may result a 35% reduction in manual bin-check methods.

Public Engagement:

Case study shows expected 50% decrease in complaints about garbage collection delays and overflows after the introduction of a citizen mobile app that allowed users to check the status of their bins and make service requests.

3. **Phase 3: Full-Scale Implementation (18–24 Months)**

The last step is to implement the smart infrastructure citywide and scale the system.

City-Wide Expansion:

Expanded GPS tracking, smart bins, and sensor-equipped trucks will be part of the smart waste management system that will be implemented in all 55 wards of Dhanbad.

Central Command Center:

Bin data, vehicle whereabouts, CCTV feeds, and analytics dashboards will be monitored in real time by a dedicated centralized control hub.

RFID-Enabled Sludge Management:

Full integration of RFID-tagged sludge containers will enable accurate tracking and reporting of coal-related waste, which can only be achieved by ongoing engagement with coal firms.

Waste Credit Scheme:

The introduction of a new incentive model, "Pay the Cost of Your Bin," is being considered with the aim of promoting responsible waste management among both families and companies. Rewarding regular, appropriate use with credits or discounts is a possibility.

7. Conclusion

One revolutionary step in updating Dhanbad's MSW management system is the use of an IoT-based MMRE approach. The city was able to prove that technology can improve accountability, sustainability, and efficiency in urban services by using real-time data, automation, and advanced analytics. Efforts to make cities cleaner, safer, and more responsive are made possible by every part of the plan, from optimized routes and smart bins to segregation made possible by artificial intelligence and platforms for citizen interaction. Through a staged approach that began with focused pilots and progressed through public-private partnerships, Dhanbad Municipal Corporation was able to reduce risks, address local difficulties, and guarantee a seamless transition to a comprehensive smart waste management ecosystem. Results such as shorter collection times, more efficient recycling, and happier citizens illustrate that the MMRE framework works. In the face of fast urbanization and garbage generation, Dhanbad's strategy provides a scalable and reproducible blueprint for cities in India and other emerging regions. As part of its MMRE plan, Dhanbad will continue to invest in infrastructure, training, and public participation in order to solve urgent urban problems through digital innovation.

References

[1] Abdallah, M., Adghim, M., Maraqa, M., & Aldahab, E. (2019). Simulation and optimization of dynamic waste collection routes. *Waste Management & Research, 37*(8), 793–802. https://doi.org/10.1177/0734242X19850563

[2] Akram, S. V., Singh, R., Gehlot, A., Rashid, M., AlGhamdi, A. S., Alshamrani, S. S., & Prashar, D. (2021). Role of wireless aided technologies in the solid waste management: A comprehensive review. *Sustainability, 13*(23), 13104. https://doi.org/10.3390/su132313104

[3] Dutta, P., Chavhan, R., Gowtham, P., & Singh, A. (2023). The individual and integrated impact of Blockchain and IoT on sustainable supply chains: A systematic review. In *Supply Chain Forum: An International Journal, 24*(1), 103–126. https://doi.org/10.1080/16258312.2023.2170870

[4] Footprints, C. (2023). Source index advances in engineering software 2023: 179, 103441 Agricultural Systems 2023: 206 Agricultural Water Management 2023: 275 Ain Shams Engineering Journal 2023: 14 (3). *Advances in Engineering Software, 179*, 103441. https://doi.org/10.1016/j.advengsoft.2023.103441

[5] Gupta, S., & Gupta, S. K. (2024). Water resource mapping, monitoring, and modeling using geospatial approaches. In *Developments in Environmental Science, 16*, 575–602. https://doi.org/10.1016/B978-0-323-85525-7.00028-0

[6] Hazra, A., Kalita, A., & Gurusamy, M. (2023). Meeting the requirements of internet of things: The promise of edge computing. *IEEE Internet of Things Journal, 11*(5), 7474–7498. https://doi.org/10.1109/JIOT.2023.3235476

[7] Joshi, L. M., Bharti, R. K., & Singh, R. (2022). Internet of things and machine learning-based approaches in the urban solid waste management: Trends, challenges, and future directions. *Expert Systems, 39*(5), e12865. https://doi.org/10.1111/exsy.12865

[8] Katariya, N. K., Choudhary, B. S., & Pandey, P. (2024). Air quality predictions through mathematical modeling for iron ore mine project. *Applied Sciences, 14*(13), 5922. https://doi.org/10.3390/app14135922

Journal of Information Systems Engineering and Management
2025, 10(51s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

[9] Khan, D., & Samadder, S. R. (2014). Municipal solid waste management using Geographical Information System aided methods: A mini review. *Waste Management & Research, 32*(11), 1049–1062. https://doi.org/10.1177/0734242X14545373

[10] Kumari, J., Shrivastava, G., Sinha, A., & Kumar, P. (2019). Role of technology in solid waste management: A review. *Recent Patents on Computer Science, 12*(4), 338–348. https://doi.org/10.2174/1872212112666190613152835

[11] Pattnaik, S. K., Samal, S. R., Bandopadhaya, S., Swain, K., Choudhury, S., Das, J. K., ... & Poulkov, V. (2022). Future wireless communication technology towards 6G IoT: An application-based analysis of IoT in real-time location monitoring of employees inside underground mines by using BLE. *Sensors, 22*(9), 3438. https://doi.org/10.3390/s22093438

[12] Rafiquee, A., & Shabbiruddin. (2024). Optimal selection and challenges of municipal waste management system using an integrated approach: A case study. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 46*(1), 1996–2023. https://doi.org/10.1080/15567036.2023.2190011

[13] Roy, S., Ghosh, S., Beck, C. D., & Sinha, A. P. (2023). Supply chain traceability: A case of blockchain modelling application to agro-business product in India. *International Journal of Sustainable Agricultural Management and Informatics, 9*(4), 295–319. https://doi.org/10.1504/IJSAMI.2023.133326

[14] Singh, A., Kumar, D., & Hötzel, J. (2018). IoT based information and communication system for enhancing underground mines safety and productivity: Genesis, taxonomy and open issues. *Ad Hoc Networks, 78*, 115–129. https://doi.org/10.1016/j.adhoc.2018.06.001

[15] Suresh, V., Agarwal, S., Chugh, Y. P., Jha, P., & Wang, R. (2025). Advancing sustainability in surface coal mines through real-time air quality monitoring: Low-cost IoT solutions and the role of meteorological factors in PM and GHG emissions. *Sustainability, 17*(3), Article 1122. https://doi.org/10.3390/su17031122

[16] Werbinska-Wojciechowska, S., & Rogowski, R. (2025). Proactive maintenance of pump systems operating in the mining industry—A systematic review. *Sensors, 25*(8), 2365. https://doi.org/10.3390/s25082365

[17] https://external-content.duckduckgo.com/iu/?u=https%3A%2F%2Ftse3.mm.bing.net%2Fth%3Fid%3DOIP.YNUvtv_MX8tGb-BfoQNLZwHaE5%26pid%3DApi&f=1&ipt=ef9a0b0c2beeb86db3198fcec839359599dac86c0c6e8233eec5426995d5cf29

[18] https://external-content.duckduckgo.com/iu/?u=https%3A%2F%2Fwww.birlasoft.com%2Fsites%2Fdefault%2Ffiles%2Fcommon%2Freal-life-examples-of-iot-based-asset-management.jpg&f=1&nofb=1&ipt=7ac6d7a8712b10a0938fc58a9cd9687ddbef9b77ee5cf575e080da8547362156

[19] Suryawan, I.W.K. and C.H. Lee. 2024. Achieving zero waste for landfills by employing adaptive municipal solid waste management services. *Ecological Indicators.,* 165: 112191.