BLOCKCHAIN BASED IOT ENHANCED WASTE COLLECTION TRACKING SYSTEM

Minor project-1 report submitted
in partial fulfillment of the requirement for award of the degree of

Bachelor of Technology
in
Information Technology

By

S. MADHURI (23UEIT0053) **(VTU25170)**
V. MAMATHA (23UEIT0059) **(VTU26149)**

Under the guidance of
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DEPARTMENT OF INFORMATION TECHNOLOGY
SCHOOL OF COMPUTING

VEL TECH RANGARAJAN DR. SAGUNTHALA R&D INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University Estd u/s 3 of UGC Act, 1956)
Accredited by NAAC with A++ Grade
CHENNAI 600 062, TAMILNADU, INDIA

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CERTIFICATE

It is certified that the work contained in the project report titled ”BLOCKCHAIN BASED IOT ENHANCED WASTE COLLECTION TRACKING SYSTEM” by S. MADHURI (23UEIT0053), V. MAMATHA (23UEIT0059) has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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November, 2025

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Signature of the Dean
Dr. S P. Chokkalingam
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November, 2025

DECLARATION

We hereby declare that the project report entitled “Blockchain-Based IoT Enhanced Waste Collection Tracking System” is a result of our own work carried out under the guidance of our project supervisor as part of our academic project work.We further declare that this written submission represents our own work and original ideas. Wherever the ideas or words of others have been included, they have been properly cited and acknowledged. We have followed all principles of academic honesty and integrity.We understand that any violation of the above principles will invite disciplinary action by the Institute and may also result in penal consequences from the original sources that have not been properly credited.

S. MADHURI

Date: / /

V. MAMATHA

Date: / /

APPROVAL SHEET

This project report entitled BLOCKCHAIN BASED IOT ENHANCED WASTE COLLECTION TRACKING SYSTEM by S. MADHURI (23UEIT0053), V. MAMATHA (23UEIT0059) is approved for the degree of B.Tech in Information Technology.

Examiners | **Supervisor**

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Assistant Professor

Date: / /
Place:

ACKNOWLEDGEMENT

We express our deepest gratitude to our **Honorable Founder Chancellor and President Col. Prof. Dr. R. RANGARAJAN B.E. (Electrical), B.E. (Mechanical), M.S (Automobile), D.Sc., and Foundress President Dr. R. SAGUNTHALA RANGARAJAN M.B.B.S.** Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, for their blessings.

We express our sincere thanks to our respected Chairperson and Managing Trustee **Mrs. RANGARAJAN MAHALAKSHMI KISHORE,B.E.,** Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, for her blessings.

We are very much grateful to our beloved **Vice Chancellor Prof. Dr.RAJAT GUPTA,** for providing us with an environment to complete our project successfully.

We record indebtedness to our **Professor & Dean, School of Computing, Dr. S P. CHOKKALINGAM, M.Tech., Ph.D., & Associate Dean, Dr. V. DHILIP KUMAR,M.E., Ph.D., Assistant Dean, Dr. R. PARTHASARATHY, M.E., Ph.D.,** for immense care and encouragement towards us throughout the course of this project.

We are thankful to our **Professor & Head, Department of Information Technology, Dr. A. PETER SOOSAI ANANDARAJ B.E., M.E., Ph.D.,** for providing immense support in all our endeavors.

We also take this opportunity to express a deep sense of gratitude to our project supervisor **Mrs. J. DEEPA., B.E., M.E.,** for her cordial support, valuable information and guidance, she helped us in completing this project through various stages.

A special thanks to our **Project Coordinator Dr. N. KATHIRVEL, M.E., Ph.D.,** for his valuable guidance and support throughout the course of the project.

We thank our department faculty, supporting staff and friends for their help and guidance to complete this project.

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ABSTRACT

The rapid growth of urban areas has led to increased waste generation, creating a need for efficient, transparent, and technology-driven waste management solutions. It proposes a digital framework for monitoring and managing the waste collection process without the use of physical sensors or hardware prototypes. Instead, it employs simulated IoT data and blockchain integration to ensure secure, tamper-proof, and transparent data sharing among key stakeholders users, waste collectors, and administrators. The proposed system conceptually combines IoT simulation, machine learning models, and blockchain verification to optimize waste collection and improve decision-making. Machine learning techniques such as Linear Regression, Random Forests, and Decision Tree algorithms are used to analyze and predict waste accumulation trends, helping authorities plan collection routes and schedules efficiently. The IoT simulation module, represented through a web or mobile interface, generates and visualizes bin status, location, and collection data, which are then securely stored and verified on a blockchain ledger. This ensures traceability, authenticity, and accountability for every recorded activity in the waste management process. Furthermore, the integration of GPS-based tracking and simulated IoT communication enables monitoring of waste bins and collection vehicles in a virtual environment. The blockchain component provides immutable records of transactions, preventing data manipulation and enhancing trust among participants. Overall, the system demonstrates how a blockchain-powered, data-driven approach can transform conventional waste collection into a more efficient, transparent, and sustainable digital process, even without the deployment of real-world sensors or hardware prototypes.

Keywords: Blockchain, IoT Simulation, Machine Learning, Linear Regression, Random Forest, Decision Tree, Data Verification, Smart Waste Management, GPS Integration, Web Interface, Digital Tracking, Waste Collection System

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LIST OF ACRONYMS AND ABBREVIATIONS

S.no	Short Cut	Abbreviations
1.	**ML**	Machine Learning
2.	**IOT**	Internet of Things
3.	**GPS**	Global Positioning System
4.	**CVS**	Comma-Separated Values
5.	**HTML**	Hypertext Markup Language
6.	**CSS**	Cascading Style Sheets

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Chapter 1

INTRODUCTION

1.1 Introduction

Efficient waste management has become a major challenge in modern urban areas due to rapid population growth, industrialization, and increasing waste generation. Traditional waste collection systems often suffer from inefficiencies such as irregular collection schedules, lack of transparency, and poor data management, leading to overflowing bins, environmental pollution, and increased operational costs. To address these challenges, integrating advanced technologies like Blockchain and the Internet of Things (IoT) provides a promising solution.

The Blockchain-Based IoT Enhanced Waste Collection Tracking System aims to create a transparent, secure, and data-driven approach to waste management. IoT technology enables continuous monitoring of waste levels and environmental conditions, while blockchain ensures that the collected data is securely recorded and cannot be altered. This combination enhances coordination between waste management authorities and service providers by ensuring that all information related to collection and disposal activities is accurate and trustworthy.

This approach helps eliminate manual record errors and unauthorized data changes while promoting transparency between the central waste management authority and collection teams. By digitally logging all operations, the system supports better route planning, scheduling, and decision-making. Ultimately, the blockchain-based framework enhances efficiency, accountability, and sustainability in urban waste management without requiring complex hardware implementations.

Moreover, the system can be easily integrated into existing municipal waste management frameworks without requiring costly hardware installations. It allows authorities to monitor collection schedules, assign vehicles efficiently, and generate digital reports for analysis and auditing. Overall, this approach promotes a smart, transparent, and eco-friendly model for urban waste management that supports sustainable city development.

1.2 Aim of the project

The main aim of the Blockchain-Based IoT Enhanced Waste Collection Tracking System is to develop a smart and transparent waste management solution that improves efficiency, accountability, and sustainability in urban waste collection processes. The project seeks to utilize the capabilities of the Internet of Things (IoT) for real-time monitoring of waste levels and integrate blockchain technology to securely store and manage data related to waste collection activities.By combining these technologies, the system aims to eliminate manual errors, prevent data manipulation, and ensure that all records of waste collection and disposal are accurate and tamper-proof.

1.3 Project Domain

The Blockchain-Based IoT Enhanced Waste Collection Tracking System belongs to the domain of Smart Waste Management, which is a subdomain of Smart Cities and Internet of Things (IoT) applications. It also integrates concepts from Blockchain Technology and Data Management Systems. This domain focuses on using advanced digital technologies to improve urban infrastructure and public services through automation, real-time monitoring, and secure data handling. By combining IoT and blockchain, the system enhances the efficiency, transparency, and accountability of waste collection and management processes. The project domain addresses key challenges in environmental sustainability, municipal operations, and data security, providing innovative solutions for efficient waste tracking, optimized collection routes, and trustworthy record keeping. Overall, this domain contributes to building intelligent, eco-friendly, and technology driven urban environments.

1.4 Scope of the Project

The scope of this project encompasses the design and development of a digital and simulation-based waste management system that integrates Blockchain, Internet of Things (IoT) (simulated), and Machine Learning (ML) technologies to improve efficiency, transparency, and accountability in waste collection and tracking processes. The proposed system aims to replicate a real-world smart waste management environment using a simulated data model, offering a scalable foundation for future deployment with actual IoT hardware. Through this integration, the system provides a unified platform for users, administrators, and waste collection authorities to interact seamlessly and make data-driven decisions.

The system's core functionality revolves around a simulation-based IoT module, which generates and transmits virtual sensor data related to waste bin parameters such as fill level, weight, and location. This simulated data mimics real-time IoT inputs and helps visualize how smart bins can function in a connected environment. The data is displayed on a web or mobile-based dashboard, allowing users to monitor bin conditions, collection statuses, and vehicle movements. This digital monitoring reduces manual oversight and enables authorities to optimize routes and collection frequencies effectively.

The Machine Learning component of the project adds an intelligent predictive layer to the system. Using the simulated IoT data, ML algorithms analyze historical waste patterns to forecast waste generation trends and predict optimal collection times. By identifying areas or bins that are likely to fill faster, the system can recommend efficient collection schedules and resource allocation. This predictive approach not only enhances operational efficiency but also contributes to fuel savings, reduced environmental pollution, and better workforce management for municipal bodies.

A crucial part of the system is the Blockchain module, which ensures secure, transparent, and immutable data management. Each event such as waste bin updates, collection records, and vehicle movements is stored as a transaction on a decentralized ledger. This immutable record prevents unauthorized data manipulation and guarantees that all stakeholders have access to the same verified information. The blockchain framework also enables traceability of waste from collection points to disposal centers, ensuring compliance with waste management regulations. Furthermore, smart contracts can automate processes such as collection confirmation, payment release, or performance logging, minimizing the need for manual verification.

While the project currently focuses on digital simulation rather than physical hardware implementation, it serves as a proof of concept for future real-world deployment. By using virtual IoT data, the system effectively demonstrates how blockchain and machine learning can work together to form a secure, intelligent, and data-driven waste collection network.

Chapter 2

LITERATURE REVIEW

2.1 Literature Review

[1]. Fahmi, F. I. et al.,(2023) proposed an IoT-driven intelligent waste management system that collects data from smart bins and integrates it into Iot-based analytics. The system effectively monitors bin status in real time, reduces overflow, and optimizes waste collection routes. Their study demonstrated the potential of IoT sensors to reduce operational costs and environmental impact through automation and data-driven decisions.

[2]. Ghaderi, Y. et al., (2024) explored how blockchain technology can overcome data security and scalability challenges in IoT-based systems. Their research highlights blockchain as a reliable tool to establish trust, enhance privacy, and ensure transparent data management in smart city applications. The study emphasizes that integrating blockchain with IoT can improve waste tracking and governance across decentralized infrastructures.

[3]. Gulyamov, S. et al., (2024) developed an integrated framework that combines IoT sensors, blockchain technology, and big data analytics to manage waste collection efficiently. Their research emphasizes how sensor-generated data can be secured and analyzed through blockchain to enable predictive maintenance and optimized scheduling. The study concludes that the synergy of these technologies enhances transparency and sustainability in waste management.

[4].Hayat, M. A., Ahmed et.al., (2024) introduced a blockchain-secured IoT framework aimed at improving waste management efficiency in urban environments. The system ensures that all waste collection and disposal data are immutably recorded on the blockchain, eliminating the risk of data tampering. Their research highlights the benefits of combining IoT automation with blockchain-based accountability to ensure transparency in municipal operations.

[5]. Khan, S. et al., (2024) designed an IoT-assisted waste collection system that employs ultrasonic and GPS sensors to monitor bin status and optimize vehicle routes. The system automatically alerts authorities when bins are full and generates efficient collection schedules. The findings show significant reductions in collection time, costs, and fuel usage, promoting smarter urban waste management practices.

[6]. Kumar, A. et al., (2024) presented a multi-layered waste management framework based on Industry 4.0 technologies, integrating IoT, blockchain, and artificial intelligence. Their approach focuses on automating the waste collection process, ensuring traceability, and improving operational efficiency. The research demonstrates how advanced digital tools can support sustainable and decentralized waste management models in smart cities.

[7]. Malagitti, S.et al., (2023) conducted a comprehensive survey of IoT and blockchain technologies in e-waste management. The authors found that blockchain enhances traceability and accountability in recycling processes, while IoT provides accurate, real-time waste tracking. The study concludes that such integrated systems can address the rising challenges of electronic waste by ensuring responsible collection and recycling.

[8]. Paul, L. et al., (2024) proposed an IoT-based waste management system for city municipalities to monitor bin levels and automate waste collection. Their design transmits real-time bin data to a centralized control system that dynamically plans vehicle routes. The study highlights how digital integration improves service delivery, reduces overflow, and enhances urban cleanliness.

[9]. Raimir, H. F. et al., (2023) developed an IoT platform based on LoRaWAN and blockchain to improve data availability for solid waste collection. The system enables long-range, low-power communication between bins and servers while ensuring blockchain-based data security. Their research demonstrates improved operational efficiency, transparency, and scalability for large urban networks.

[10]. Saad, M. et al., (2023) created a blockchain-enabled vehicular ad-hoc network (VANET) for smart solid waste management. The proposed system records vehicle movements and collection activities securely on the blockchain, ensuring transparency and accountability. Their framework improves coordination, reduces redundancies, and enhances the reliability of waste transportation operations.

2.2 Gap Identification

Despite the growing adoption of smart waste management solutions, several critical gaps remain in current research and implementations. Most IoT-based waste collection systems effectively monitor bin status and optimize collection routes, but they often fail to ensure data integrity, transparency, and interoperability across different organizations or municipalities. The absence of a trusted and decentralized data management framework makes such systems prone to data manipulation, inefficiencies, and poor coordination between stakeholders. Additionally, traditional centralized databases used in existing models present security vulnerabilities, single points of failure, and limited scalability, especially when deployed across large urban areas.

Another major gap lies in the lack of integration between IoT data and blockchain-based verification. While blockchain offers features like immutability, traceability, and decentralized control, few systems have successfully merged these benefits with real-time IoT data for waste management. Furthermore, many studies overlook the potential of blockchain smart contracts for automating operations such as service verification, payments, and performance tracking. There is also limited research on integrating artificial intelligence or data analytics with blockchain and IoT to generate predictive insights for efficient decision-making. In addition, energy consumption, cost efficiency, and network latency remain major technical challenges when deploying blockchain with IoT. The lack of standardization and interoperability between different IoT platforms and blockchain frameworks further limits large scale implementation.

Therefore, there exists a clear research and implementation gap in developing a secure, transparent, scalable, and data driven waste collection tracking system that combines IoT's capabilities with blockchain's data integrity features. Addressing these gaps can lead to a more sustainable, efficient, and accountable waste management ecosystem for smart cities.

Chapter 3

PROJECT DESCRIPTION

3.1 Existing System

In the existing waste management system, most municipalities and private contractors rely on manual or semi-automated methods to manage the collection and disposal of waste. Data regarding waste pickup schedules, vehicle movements, and disposal locations are often recorded using traditional databases or paper-based logs. These systems operate in a centralized manner, where all information is stored and controlled by a single authority, such as the municipal department. This centralization makes it difficult to ensure transparency among multiple stakeholders like collection workers, contractors, and monitoring officials. In many cases, communication between these entities occurs through phone calls or spreadsheets, resulting in inconsistencies and delayed reporting. As a result, real-time tracking and verification of waste collection activities become nearly impossible, leading to inefficiencies in operations and improper waste handling. The major disadvantage of the existing system is its lack of transparency, security, and accountability. Since the data is managed in a centralized database, it is prone to tampering, data loss, or manipulation by unauthorized users. There is no secure mechanism to verify whether waste was actually collected or properly disposed of, which can lead to false reporting and misuse of resources. Manual record-keeping also introduces human errors and delays in updating information, making it difficult to monitor progress or detect issues promptly. Moreover, there is no automated verification or auditing process to ensure the authenticity of records, leading to reduced public trust and inefficiency in waste management operations.Overall, the existing systems are effective in basic monitoring but lack the integration of blockchain technology, which can provide enhanced security, transparency, and data integrity. This creates the need for a more advanced and reliable solution that combines IoT and blockchain to ensure trustworthy, efficient, and sustainable waste management operations.

3.2 Problem statement

The current waste management systems face several challenges related to data integrity, transparency, and coordination among different stakeholders. In many urban and municipal setups, the waste collection process is monitored using manual entry systems or centralized databases. These systems are highly vulnerable to data manipulation, delays, and inefficiencies. There is often no reliable mechanism to verify whether the recorded waste collection and disposal activities are authentic or accurate. This lack of transparency leads to mismanagement, improper billing, and loss of accountability among authorities, contractors, and workers.

Additionally, as there is no automated record validation, the process depends heavily on manual supervision, which increases the risk of human errors and operational delays. The proposed Blockchain Based IoT Enhanced Waste Collection Tracking System aims to overcome these limitations by using blockchain's decentralized and immutable data storage mechanism. This system ensures that all records of waste collection, transfer, and disposal are securely stored and transparently accessible to all authorized stakeholders. Each transaction is verified through smart contracts, eliminating the need for intermediaries and manual checking. The key advantages of the proposed system include improved transparency, enhanced data security, real-time tracking, automation of verification processes, and prevention of data tampering. Moreover, the blockchain framework promotes trust and accountability, as every transaction is timestamped and permanently recorded.

This leads to a more efficient, reliable, and environmentally responsible waste management process, suitable for modern smart city implementations. Additionally, in many current systems, data collected from IoT sensors is not securely shared or verified, leading to possible manipulation or misreporting of waste collection activities. This lack of trust and transparency creates difficulties for municipal authorities in auditing performance, verifying operations, and ensuring proper waste disposal. Moreover, these systems often struggle to scale effectively, as interoperability issues arise when integrating devices and data across different organizations or city zones. Therefore, the core problem is the absence of a secure, transparent, and decentralized mechanism that can record and verify every step of the waste collection process in real time. The challenge lies in combining IoT's real-time monitoring capabilities with blockchain's immutability and distributed .

3.3 System Specification

3.3.1 Hardware Specification

The proposed Blockchain Based IoT Enhanced Waste Collection Tracking System is a software-oriented project that focuses on the conceptual and simulation aspects of blockchain integration with IoT. Since no physical sensors, devices, or hardware prototypes are implemented, the system operates entirely in a virtual or simulated environment. Hence, no specialized hardware components are required apart from a basic computing setup to develop, test, and demonstrate the software model.

- RAM: Minimum 4 GB (8 GB recommended for smooth execution)
- Storage: At least 256 GB free disk space for development tools and data files
- Internet Connection: Stable connection for accessing blockchain and cloud services
- Operating System: Windows 10/11 or Ubuntu 22.04 LTS (64-bit)

3.3.2 Software Specification

The proposed Blockchain Based IoT Enhanced Waste Collection Tracking System is fully software-based and focuses on the conceptual and simulation aspects of blockchain and IoT integration. Since no physical prototype is implemented, all functionalities are modeled and executed using software tools, frameworks, and programming environments. The software stack ensures efficient data management, secure transaction processing, and blockchain ledger maintenance. The following software specifications are recommended for system design, implementation, and testing:

- Blockchain Platform: Ethereum / Hyperledger Fabric (for decentralized ledger and smart contracts)
- Blockchain Development Tools: Ganache, Remix IDE, Truffle Suite (for smart contract creation and testing)
- (Integrated Development Environment): Visual Studio Code / PyCharm (for coding and debugging)

3.3.3 Standards and Policies

Python

Python is the primary programming language used for developing the blockchain-based waste collection tracking system. It is a high-level, interpreted language compatible with Windows, Linux, and macOS. Python provides extensive libraries and frameworks for blockchain integration, data handling, and building web-based user interfaces for monitoring waste collection activities. The UI and logic of the system can be implemented entirely in Python, making development and testing easier. **Standard Used: ISO/IEC 27001**

Jupyter Notebook

It is an open-source web application that allows developers to create and share documents containing live code, equations, visualizations, and narrative text. It can be used in this project for simulating waste collection events, testing smart contract functionality, and visualizing blockchain transaction data. It also allows iterative testing and debugging of Python-based blockchain integration.

HTML(HyperText Markup Language)

HTML is used to design the front-end interface of the system where waste management authorities can monitor collection activities and view blockchain transaction data. It defines the structure and layout of web pages, displaying data such as waste bin status, collection requests, and transaction history. HTML ensures that all visual components are presented in a clean, user-friendly format for easy accessibility and usability across browsers and platforms. **Standard Used: W3C HTML5**

Chapter 4

METHODOLOGY

4.1 Proposed System

The proposed system introduces a sensor-less, software-driven smart waste collection tracking framework that utilizes simulated IoT data, Machine Learning analytics, GPS-based vehicle monitoring, and blockchain-enabled verification to overcome the limitations of traditional waste management processes. Instead of relying on physical sensors, the system incorporates a web or mobile application interface through which waste collection authorities, drivers, and citizens can manually update bin status information such as estimated fill levels, overflow alerts, or collection confirmation. This interface collects time-stamped event data and GPS coordinates from collection vehicles, enabling virtual monitoring of bin conditions and route activity. The simulated IoT environment generates realistic bin-level variations, eliminating the need for costly hardware deployment while still providing meaningful operational data.

Machine Learning algorithms including Linear Regression, Decision Tree, and Random Forest are applied to analyze historical and simulated waste patterns to predict high-waste zones, forecast future waste generation, optimize collection schedules, and prioritize bins requiring immediate attention. These predictive insights improve route planning, reduce fuel consumption, and prevent waste overflow within densely populated areas. The system also integrates GPS tracking to validate whether a waste collection vehicle has visited a specific bin location, ensuring that routes are followed correctly.

To ensure transparency, authenticity, and tamper-proof record keeping, the system employs a blockchain-based ledger, where every collection event, GPS update, and service confirmation is stored as a secure, immutable transaction. This prevents data manipulation, eliminates false reporting, and supports clear auditing between municipal authorities, contractors, and waste management workers. The system architecture is centered around a web and mobile-based application interface, which serves as the primary interaction point for waste management authorities, collection vehicle drivers, and citizens. Through this interface, users can manually input or update bin statuses such as “Empty,” “Half-Full,” “Full,” or “Overflow,” along with optional notes or images. Each update is automatically timestamped and paired with GPS coordinates from the user’s device, allowing for precise location tracking of collection events.

This eliminates the need for hardware-based sensing mechanisms while still generating accurate, time-bound operational data. A simulated IoT environment is implemented within the system to generate dynamic and realistic waste-level variations across multiple bins and zones. This allows developers and analysts to test system functionality, validate data handling procedures, and visualize trends in waste accumulation without deploying physical prototypes. The Central Server component aggregates this simulated data and processes it using Machine Learning algorithms such as Linear Regression, Decision Tree, and Random Forest.

These algorithms analyze both historical and simulated datasets to identify high-waste generation areas, predict future waste volumes, and recommend optimized collection schedules. This predictive capability helps authorities prioritize collection routes, reduce fuel consumption, and prevent bin overflow particularly in densely populated or high-traffic urban regions. The integration of GPS tracking further strengthens the operational reliability of the system. Each collection vehicle is digitally mapped and monitored in real-time, ensuring that scheduled routes are followed accurately. The system automatically verifies whether a vehicle has reached a designated bin location by cross-referencing GPS logs with pre-defined collection coordinates. This ensures route compliance and minimizes missed collections or duplicate reports.

4.2 General Architecture

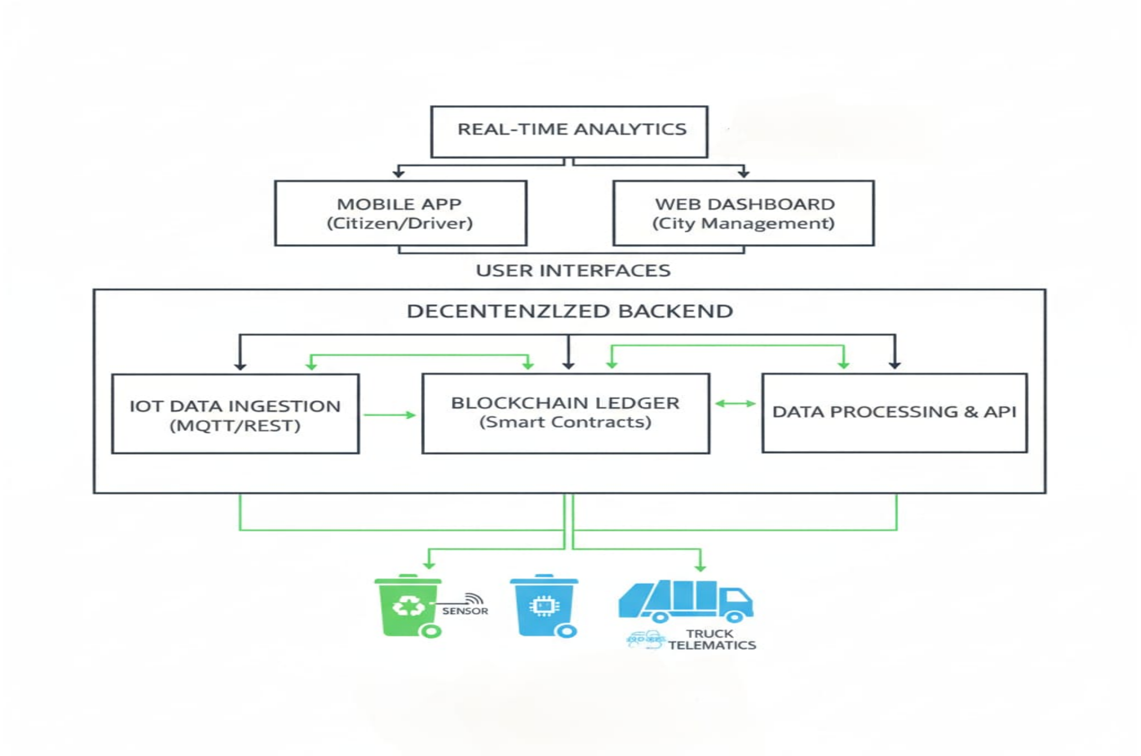

Figure 4.1: **General Architecture Of Waste Collection Tracking system**

Figure 4.1 represents the overall architecture of a Blockchain-Based IoT Enhanced Waste Collection Tracking System. It integrates three modules:

- Module 1: Machine Learning uses Linear Regression, Random Forests, and Decision Trees for predictive intelligence.The Machine Learning Module plays a crucial role in the proposed blockchain-based waste collection tracking system by providing predictive intelligence for efficient waste management operations.
- Module 2: IOT simulates GPS Location and sensor data, input primarily through a Mobile App Interface and Web Dashboard.This simulated IoT environment generates dynamic variations in bin fill levels and collection frequency, helping the system test and analyze performance under different conditions.
- Module 3: Blockchain Integration Used to processes and validates this data. The Central Server facilitates the flow, sending validated records to the Decentralized Blockchain Network for secure, immutable tracking and transparency. This prevents unauthorized modifications and ensures complete traceability of all waste management activities.

4.3 Design Phase

4.3.1 Data Flow Diagram of Waste Collection Tracking system

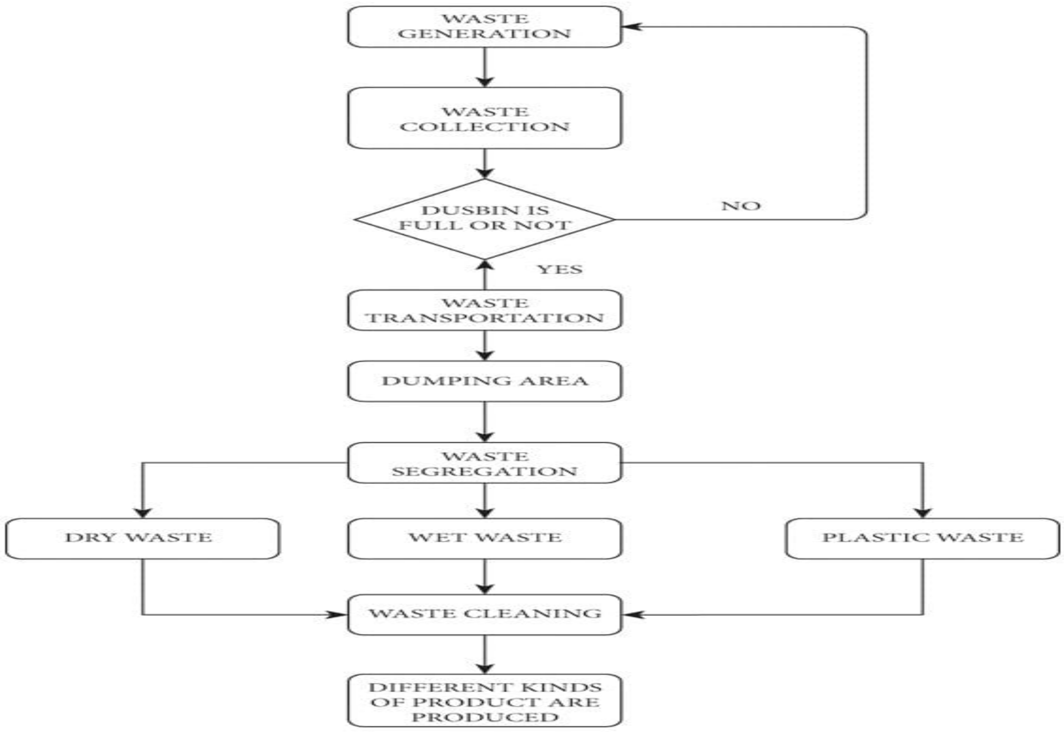

Figure 4.2: **Data Flow Diagram Of Waste Collection Tracking system**

Figure 4.2 represents the overall process of waste management, beginning with waste generation and ending with the production of different kinds of useful products. The process starts when waste is generated and then collected in designated bins. A monitoring step checks whether the dustbin is full or not. If the bin is not full, the waste collection continues otherwise, once the bin is full, the waste is transported to a dumping area. At the dumping site, waste segregation takes place, where waste is divided into dry waste, wet waste, and plastic waste. Each category of waste undergoes a cleaning process to ensure that it is suitable for reuse or recycling. Finally, from the cleaned and processed waste materials, different kinds of products are produced, promoting recycling and sustainable waste management. This flowchart clearly represents an efficient waste collection and processing system aimed at minimizing environmental impact.

4.3.2 Use Case Diagram of Waste Collection Tracking system

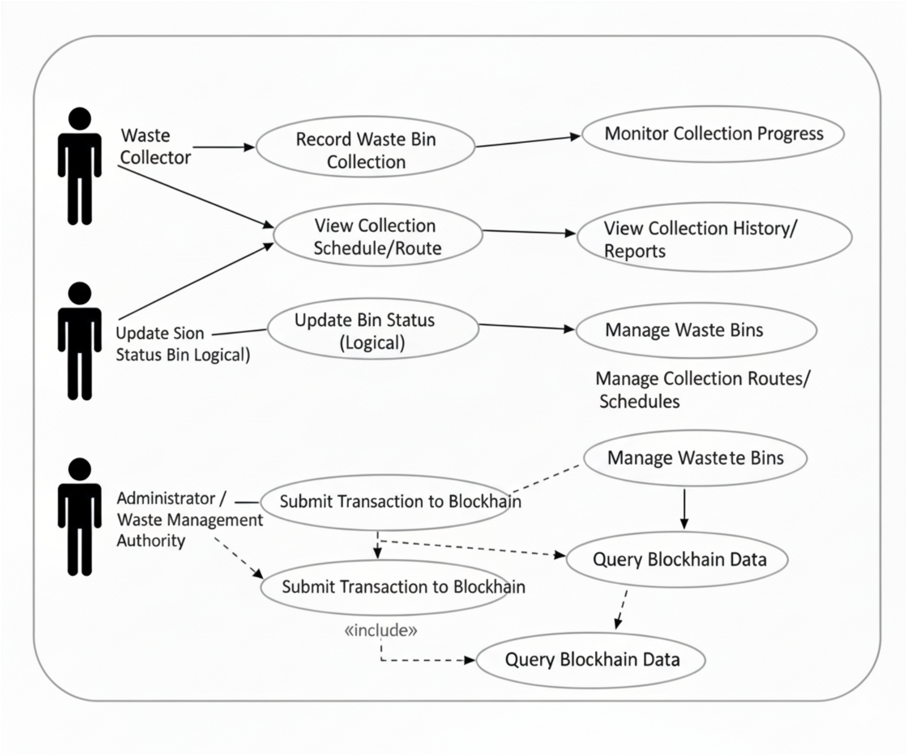

Figure 4.3: **Use Case Diagram Of Waste Collection Tracking system**

Figure 4.3 represents the Blockchain-Based IoT Enhanced Waste Collection Tracking System. The interaction between different actors and the system's main functionalities. The key actors include the Local Waste Collector, City Administrator, Collection Manager, and the IoT Bin. Each actor interacts with the system to perform specific operations essential for effective waste management. The IoT Bin acts as a smart device that continuously monitors waste levels and environmental conditions such as temperature or gas emissions. It automatically sends real-time data to the system, triggering necessary actions when the bin reaches its threshold. The Local Waste Collector receives notifications or alerts from the system and performs waste collection tasks.

4.3.3 Class Diagram of Waste Collection Tracking system

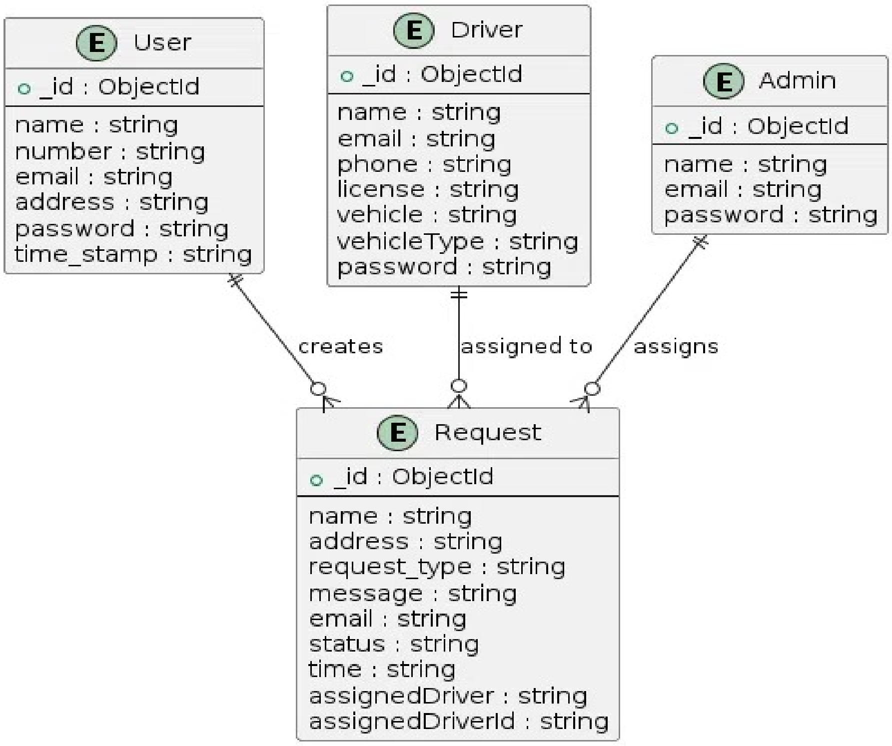

Figure 4.4: **Class Diagram Of Waste Collection Tracking system**

Figure 4.4 represents an Class diagram model for a waste collection and management system, involving four main entities: User, Driver, Admin, and Request. The User entity includes attributes such as name, contact number, email, address, password, and timestamp, representing the citizens or clients who generate waste and make service requests. The Driver entity stores details about the waste collection drivers, including their name, email, phone number, license, vehicle type, and password. The Admin entity contains the administrator's credentials like name, email, and password, who manages the system's operations. The Request entity serves as a central link connecting the other three entities and includes details such as name, address, request type, message, email, status, time, and the assigned driver details. The relationships depicted show that a User creates a request, an Admin assigns the request, and a Driver is assigned to handle it. This ER diagram effectively models how users, administrators, and drivers interact in a coordinated way to manage and process waste collection requests efficiently.

4.3.4 Sequence Diagram of Waste Collection Tracking system

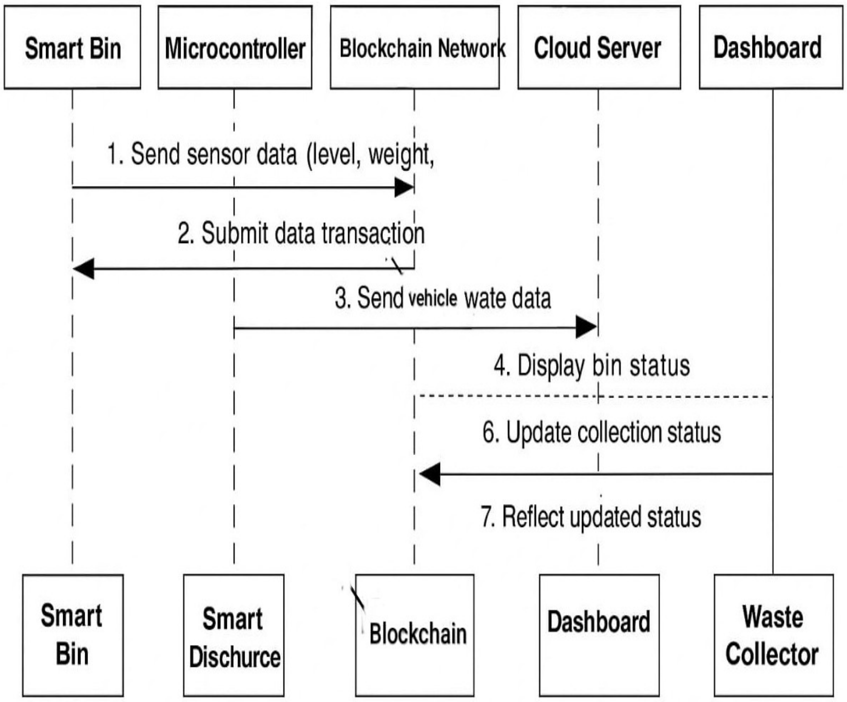

Figure 4.5: **Sequence Diagram Of Waste Collection Tracking system**

Figure 4.5 represents the Waste Collection Tracking System, the step-by-step flow of interactions between different system components to manage waste efficiently. The process begins with the Waste Generator, which identifies a pickup request based on the location, waste type, and bin fill level. The IoT Bin Sensor continuously monitors the waste bin's fill level and transmits real-time data to the Local Gateway or Hub. The hub forwards this information to the Blockchain Network, where data is securely stored using smart contracts to ensure transparency and traceability. The Waste Collection Vehicle receives the notification and route details through its tracking application, confirming the collection route and estimated arrival time. Once the waste is collected, the vehicle confirms the collection details such as location and timestamp, and this data is again stored in the blockchain.

4.3.5 Collaboration diagram of Waste Collection Tracking system

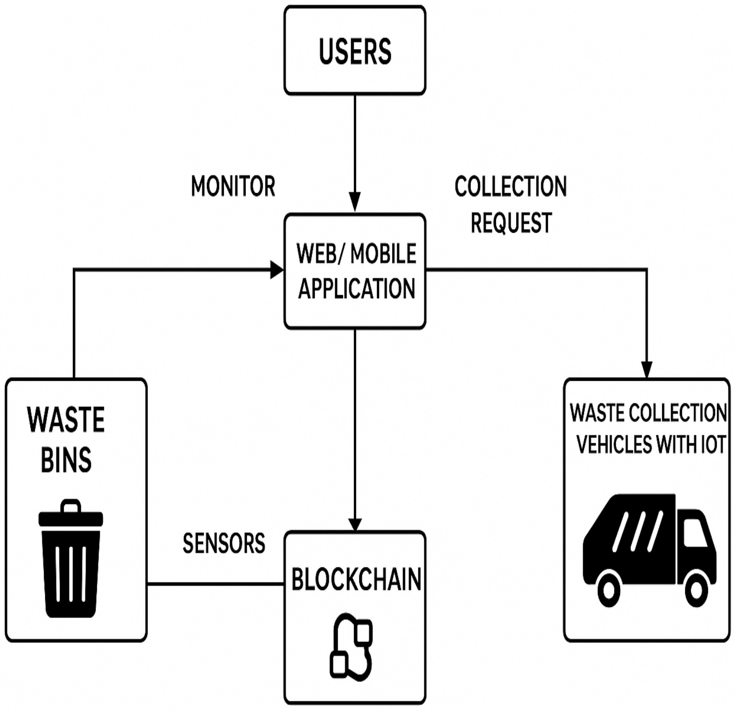

Figure 4.6: **Collaboration diagram Of Waste Collection Tracking system**

Figure 4.6 represents the collaboration diagram for a Blockchain-Based IoT Enhanced Waste Collection Tracking System.The structural relationships and message interactions among the system's key components that work together to ensure secure, efficient, and transparent waste management. The main objects involved are the IoT Sensor Node, Waste Bin, Central Server, Blockchain Network, Waste Management Authority, and Collection Vehicle. The IoT Sensor Node embedded in the waste bin detects the fill level and environmental data, sending this information to the Central Server when a threshold is reached. The Central Server processes the data, validates it, and communicates with the Blockchain Network to store it as a tamper-proof transaction. The Waste Management Authority interacts with the blockchain to retrieve and review pending collection requests. After verifying the details, it assigns the nearest Collection Vehicle for pickup.

4.3.6 Activity Diagram of Waste Collection Tracking system

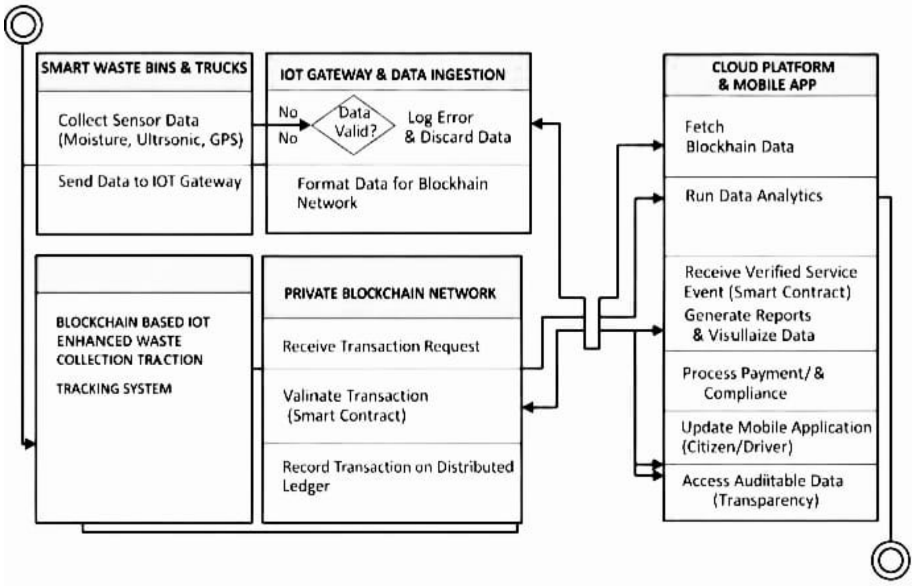

Figure 4.7: **Activity Diagram Of Waste Collection Tracking system**

Figure 4.7 represents the activity diagram for a Blockchain-Based IoT Enhanced Waste Collection Tracking System. The sequential flow of operations and decision-making processes that ensure efficient and transparent waste management using blockchain technology. The process begins with the Waste Management Authority or operator updating the status of each waste bin in the Central Server database. When a bin is identified as full, the Central Server generates a new waste collection request containing the bin ID, location, and time. This request is then forwarded to the Blockchain Network, where it is verified and recorded as a secure, immutable transaction. Once the transaction is successfully stored, the Waste Management Authority reviews the blockchain record and assigns a Collection Vehicle for pickup. The Collection Vehicle proceeds to the location, collects the waste, and reports completion details such as time and bin ID back to the Central Server.

4.4 Algorithm & Pseudo Code

4.4.1 Algorithm: Rule-Based Waste Collection Tracking System

Step 1: Start

Initialize system modules Waste Bin Manager (WB), User Authentication Module (UA), Central Server (CS), Machine Learning Predictor (ML), Blockchain Ledger (BC), and Report Generator (RG).

Step 2: Input Initialization

Manually collect waste bin data through the web or mobile interface. Each bin record includes: *Bin ID, Location, Capacity, and Status ("Empty," "Half-Full," "Full").* Authority credentials (username, password) are verified through UA for secure access.

Step 3: Update Bin Status

Authorized personnel or citizens manually update bin conditions in the system:

$$WasteBin.Update(bin\_id, status, timestamp)$$

These updates are sent to the Central Server (CS) for processing and logging.

Step 4: Validate and Record Transaction

For each status update, the Central Server validates input fields and user credentials. Once verified, a new transaction record is created:

$$Tx = \{Bin\_ID, Status, Updated\_By, Timestamp\}$$

The transaction is forwarded to the Blockchain Module for immutable storage.

Step 5: Add Transaction to Blockchain

The Blockchain Module verifies and adds the transaction to the distributed ledger:

$$BlockChain.AddBlock(Tx)$$

Each block includes a hash of the previous block, ensuring security and transparency.

Step 6: Machine Learning Prediction (Simulated IoT)

The ML module analyzes historical and simulated data to predict upcoming waste levels:

$$Predicted\_Fill\_Level = MachineLearning.Predict(Bin\_ID, Historical\_Data)$$

If the prediction indicates overflow risk, the system triggers an alert for collection scheduling.

Step 7: Vehicle Assignment and Route Optimization

The Central Server assigns the nearest available vehicle based on bin location and collection priority:

$$Vehicle\_Assignment = CentralServer.AssignVehicle(Bin\_Location, Status)$$

Route optimization logic minimizes fuel use and travel time.

Step 8: Collection Confirmation

After pickup, the vehicle operator manually confirms the collection status via mobile interface:

$$WasteBin.UpdateStatus(Bin\_ID, “Collected'', Timestamp)$$

This confirmation is again recorded as a blockchain transaction for verification.

Step 9: Report Generation

The system generates daily or weekly performance reports including:

(i) Number of bins collected
(ii) Pending vs. completed collections
(iii)Verified blockchain transactions
(iv) Vehicle efficiency metrics

$$ReportGeneration.GenerateReport(Date\_Range)$$

Step 10: Notifications and Alerts

Notifications are automatically sent to Waste Management Authorities for:

(i) Overflowing bins
(ii) Pending collections
(iii) Completed pickups

$$CentralServer.Notify(Authorities, Alerts)$$

Step 11: Display Dashboard Output All verified data is visualized on the web dashboard, showing:

(i) Bin statuses and locations

(ii) Vehicle routes

(iii) Blockchain verification summary

(iv) Predictive waste analytics

Step 12: End

System workflow ends after all updates, blockchain entries, and notifications are successfully completed

4.4.2 Pseudo Code

```
    BEGIN

// Step 1: Initialize system components
INITIALIZE WasteBinDatabase
INITIALIZE BlockchainLedger
INITIALIZE CentralServer
INITIALIZE WasteManagementAuthority
INITIALIZE CollectionVehicles

// Step 2: Register waste bins in the system
FOR each bin IN city_bins DO
    CREATE record(bin_ID, location, status = "Empty")
    STORE record IN WasteBinDatabase
END FOR

// Step 3: Update bin status (manual or digital input)
FOR each bin IN WasteBinDatabase DO
    IF bin_status = "Full" THEN
        CALL CreateCollectionRequest(bin_ID, location)
    END IF
END FOR

// Step 4: Function to create collection request
FUNCTION CreateCollectionRequest(bin_ID, location)
    transaction = {
        Type: "Collection_Request",
        Bin_ID: bin_ID,
        Location: location,
        Timestamp: CURRENT_TIME
    }
    ADD transaction TO BlockchainLedger
    NOTIFY WasteManagementAuthority(transaction)
```

```
END FUNCTION

// Step 5: Assign collection vehicle
FOR each pending_request IN BlockchainLedger DO
    IF pending_request.Status = "Unassigned" THEN
        ASSIGN vehicle TO pending_request
        UPDATE request.Status = "Assigned"
    END IF
END FOR

// Step 6: Simulate waste collection
FOR each assigned_vehicle DO
    PERFORM waste_collection AT assigned_location
    CALL UpdateCollectionCompletion(bin_ID)
END FOR

// Step 7: Function to update collection completion
FUNCTION UpdateCollectionCompletion(bin_ID)
    transaction = {
        Type: "Collection_Completion",
        Bin_ID: bin_ID,
        Timestamp: CURRENT_TIME
    }
    ADD transaction TO BlockchainLedger
    SEND confirmation TO CentralServer
END FUNCTION

// Step 8: Generate report
GENERATE summary_report FROM BlockchainLedger
DISPLAY report TO WasteManagementAuthority

END
```

4.4.3 Generation of Data

In the Blockchain-Based IoT Enhanced Waste Collection Tracking System, the data set or generation of data is simulated or manually created to represent the real-world waste collection process without using physical IoT devices. The data primarily includes essential attributes such as Bin ID, Location, Waste Level Status5 , Timestamp, Collection Status, and Vehicle ID. This data can be generated through manual entry by municipal staff or automated scripts that simulate waste accumulation patterns over time. Each record in the dataset represents a specific waste bin's condition and its corresponding collection cycle. When a bin status changes to "Full," the system generates a waste collection request, which is treated as a new data entry and subsequently recorded as a blockchain transaction for immutability and transparency. After collection, another dataset entry is created to update the collection status as "Completed," along with date and time.

- Waste Bin Data API
  Purpose: Fetch and update bin details such as Bin ID, location, capacity, and status.
  Endpoint: https://smartwastemanagement.gov/api/bins
  Data Format: JSON (Bin$_ID, Location, Capacity, Status, Last_Updated)$

- Blockchain Transaction API
  Purpose: Record and verify waste collection transactions on the blockchain ledger.

  Endpoint: https://blockchainwastetrack.org/api/transactions. Data Format: JSON (Transaction$_Type, Bin_ID, Timestamp, Authority, Remarks)$

- Reporting and Monitoring API Purpose: Generate and fetch daily, weekly, or monthly collection performance reports.
  Endpoint: https://smartwastemanagement.gov/api/reports
  Data Format: JSON (Date$_Range, Bin_Status, Vehicle_ID)$
  $Output: Collectionsummary, efficiencyscore, andblockchainverificationstatus.$

4.5 Module Description

4.5.1 Module 1: Machine Learning-Based Predictive Waste Analysis and Optimization Module

Machine Learning in the proposed system plays a vital role in transforming raw and simulated waste data into actionable insights for predictive waste collection management. By leveraging supervised learning algorithms, the system can learn from historical records, collection logs, and simulated data to predict future waste generation patterns and optimize collection strategies.

Linear Regression is employed to estimate expected waste volume in different zones by considering multiple factors such as population density, day of the week, seasonal variations, and historical waste trends. This helps municipal authorities plan timely waste pickups and allocate resources efficiently.

Decision Tree algorithms use a hierarchical, condition-based structure to categorize bins based on urgency, such as “Immediate Collection,” “Scheduled,” or “Normal.” This allows the system to make rule-based, interpretable decisions that are easy for operators to understand.

To enhance prediction reliability, Random Forest, an ensemble of multiple decision trees, is used to minimize overfitting and improve accuracy by averaging results from different models. This enables robust forecasting of high-waste zones, identification of overflow-prone bins, and optimization of collection routes.

Furthermore, the Machine Learning module continuously updates its predictive models with new data generated from the system’s blockchain and simulated IoT modules, ensuring adaptive learning and continuous performance improvement. Ultimately, this module provides a data-driven foundation for proactive waste management, reducing manual errors and improving overall operational efficiency.

4.5.2 Module 2: Simulated IoT-Based Waste Monitoring and GPS Tracking Module

In the proposed system, the Internet of Things (IoT) concept is simulated entirely through software-based interaction, eliminating the need for physical sensors while retaining the essential functionality of real-time monitoring and data collection. The system leverages a web or mobile application that enables manual bin status updates by users such as citizens, collection workers, or municipal staff. Each update such as marking a bin as "Empty," "Half-Full," "Full," or "Overflowing" is automatically linked with a timestamp and GPS location, replicating sensor-based IoT functionality in a digital form.

The GPS tracking feature plays a vital role in ensuring transparency and route accuracy. Every time a waste collection vehicle or user reports a bin's condition, the system captures latitude and longitude data using the device's GPS or web map APIs. This allows the platform to monitor vehicle movement, collection coverage, and bin location verification in real-time. Authorities can visualize this data on an interactive dashboard, making it easier to assess which areas require immediate attention or where collection delays are occurring.

The simulated IoT framework also generates automated event logs to maintain a digital trail of all bin interactions, collection updates, and location changes. These logs can later be analyzed by the Machine Learning module to identify waste generation trends and predict future collection needs.

One of the main advantages of this simulated IoT approach is its cost-effectiveness and scalability. It reduces the dependency on physical sensors, minimizes maintenance costs, and allows seamless deployment in urban as well as semi-urban areas. Moreover, it offers flexibility in customization, as data input methods, bin categories, and collection parameters can be modified through software updates without hardware changes.

When integrated with the Blockchain Verification Module, the simulated IoT data becomes secure, traceable, and tamper-proof, ensuring that all bin status updates and location records remain authentic. Overall, this module provides a practical, efficient, and sustainable alternative to traditional IoT hardware-based waste monitoring systems.

4.5.3 Module 3: Blockchain-Based Data Verification and Transparency Module

This blockchain based data verification module ensures the security, transparency, and reliability of all waste collection data by integrating blockchain technology into the system's backend architecture. The blockchain acts as a decentralized and tamper-proof digital ledger, where every waste collection event, bin update, or route verification is recorded as an immutable transaction. This eliminates the possibility of data manipulation, unauthorized changes, or false reporting, thus enhancing the overall accountability of the waste management process.

Whenever a bin's status is updated through the web or mobile interface, the system automatically generates a blockchain transaction. Each transaction contains critical details such as the Bin ID, Collector ID, Location, Timestamp, and Action Type (e.g., "Collection Request," "Collection Completed"). Once created, this transaction is broadcasted to the Blockchain Network, where multiple validating nodes verify its authenticity using a consensus mechanism before it is permanently added to the ledger.

The Verification Process ensures that only legitimate data from authenticated users and authorized personnel is recorded. Each transaction undergoes cryptographic validation including hash generation and signature verification ensuring data integrity and preventing duplication or tampering. The Traceability Feature of the blockchain allows administrators and auditors to trace the complete lifecycle of a waste collection event, from the initial request to the final confirmation of pickup.

Furthermore, the Transparency Mechanism of blockchain enables municipal authorities, service providers, and even citizens to view and confirm real-time collection records. This open verification model builds public trust by allowing stakeholders to confirm when and where bins were serviced, promoting honesty and efficiency among collection staff. In summary, the Blockchain Integration and Verification Module provides a secure, auditable, and transparent data management layer for the entire waste collection tracking system. By eliminating centralized control and introducing decentralized verification, it enhances system trust, operational integrity, and long-term reliability for municipal waste management authorities.

Chapter 5

IMPLEMENTATION AND TESTING

5.1 Input and Output

Input:

In this project, all input data is collected manually through a web or mobile interface, eliminating the need for sensors or hardware prototypes. Waste bin details such as bin ID, location, capacity, and current fill-level are updated by users or collection staff. Authorized personnel, such as waste management authorities, provide login credentials, vehicle IDs, and driver details for tracking and authentication. The system also records blockchain-based transaction details for each collection request and completion, ensuring data transparency and security. Additionally, collection updates including vehicle status, pickup confirmation, and completion time are manually entered to maintain an accurate and efficient digital record of waste collection activities.

5.1.1 Input Code

```
    BEGIN
   # --- Input Module: Blockchain-Based Waste Collection Tracking System ---
from datetime import datetime
# Class to store waste bin information
class WasteBin:
    def __init__(self, bin_id, location, capacity, status="Empty", last_updated=None):
        self.bin_id = bin_id
        self.location = location
        self.capacity = capacity
        self.status = status
        self.last_updated = last_updated or datetime.now().strftime("%Y-%m-%d %H:%M:%S")
 def update_status(self, new_status):
        self.status = new_status
        self.last_updated = datetime.now().strftime("%Y-%m-%d %H:%M:%S")
# Class to store user/authority information
class UserAuthority:
    def __init__(self, username, role, vehicle_id=None, driver_name=None):
```

```
        self.username = username
        self.role = role
        self.vehicle_id = vehicle_id
        self.driver_name = driver_name
# Blockchain transaction simulator
class BlockchainTransaction:
    def __init__(self, tx_type, bin_id, authority, remarks=""):
        self.tx_type = tx_type
        self.bin_id = bin_id
        self.authority = authority
        self.timestamp = datetime.now().strftime("%Y-%m-%d %H:%M:%S")
        self.remarks = remarks
 def display(self):
        print(f"[{self.tx_type}] | Bin: {self.bin_id} | User: {self.authority.username} "
              f"| Time: {self.timestamp} | Remarks: {self.remarks}")

# Initialize some sample input data
bins = [
    WasteBin("BIN-001", "Zone A", "50L"),
    WasteBin("BIN-002", "Zone B", "80L"),
    WasteBin("BIN-003", "Zone C", "100L")
]

authority = UserAuthority("Admin123", "Waste Management Officer", "VH-101", "Rahul Das")

# Simulate bin status update (manual input)
bins[0].update_status("Full")
bins[1].update_status("Half-Full")

# Create blockchain transactions for collection requests
tx1 = BlockchainTransaction("Collection_Request", bins[0].bin_id, authority, "Marked Full")
tx2 = BlockchainTransaction("Collection_Request", bins[1].bin_id, authority, "Half-Full status logged")

# Display inputs and transactions
print("---- Waste Bin Data ----")
for bin in bins:
    print(f"ID: {bin.bin_id}, Location: {bin.location}, Capacity: {bin.capacity}, "
          f"Status: {bin.status}, Last Updated: {bin.last_updated}")

print("\n---- Blockchain Transactions ----")
tx1.display()
tx2.display()
```

Output:

The system provides a real-time display of waste bin statuses such as Empty, Half-Full, or Full, by continuously monitoring data from IoT sensors such as ultrasonic and weight sensors. When a bin reaches a critical level, an automatic alert is generated and sent to the control dashboard, prompting an immediate collection request. All collection requests, acknowledgments, and completion records are securely stored as transactions on the blockchain network, ensuring data immutability, transparency, and traceability throughout the waste management process.

Using smart contracts, the system automates the assignment of vehicles based on parameters like bin location, fill level, and route proximity. This intelligent scheduling reduces manual intervention, minimizes fuel consumption, and optimizes collection routes for greater operational efficiency. The integrated GPS module tracks the real-time movement of waste collection vehicles, allowing administrators to monitor task progress and ensure timely service.

Furthermore, the platform generates daily, weekly, and monthly analytical reports, summarizing the total waste collected, number of bins serviced, vehicle performance, and blockchain-verified entries. These reports support data-driven decision-making and improve accountability within municipal or private waste management organizations.

5.1.2 Output Code

```
---- Waste Bin Data ----
BIN-001 | Zone A | 50L | Full | Updated: 2025-10-28 14:39:40
BIN-002 | Zone B | 80L | Half-Full | Updated: 2025-10-28 14:39:40
BIN-003 | Zone C | 100L | Empty | Updated: 2025-10-28 14:39:40

---- Blockchain Transactions ----
[Collection_Request] Bin:BIN-001 | User:Admin123 | Time:2025-10-28 14:39:40 | Marked Full
[Collection_Request] Bin:BIN-002 | User:Admin123 | Time:2025-10-28 14:39:40 | Half-Full Logged
```

5.1.3 Input Design

1. Waste Bin Data Inputs

Each waste bin is assigned a unique Bin ID, location (latitude and longitude), and capacity information. Fill-level data is collected either manually by municipal staff or automatically through IoT installed in the bins. The system captures timestamped readings of the bin's status (Empty, Half-Full, Full) to monitor collection needs. These inputs are transmitted to the Central Server for processing and stored securely for reference.

2. User and Authority Authentication Inputs

Authorized personnel such as Waste Management Officers and Vehicle Operators provide their username, email, and password to log into the system. Passwords are encrypted before storage to ensure security and prevent unauthorized access. The system validates user credentials before allowing data entry, blockchain transaction submission, or report access.

3.Collection and Vehicle Operation Inputs

Collection vehicle details, including Vehicle ID, driver name, and route information, are entered by the Waste Management Authority. When a bin is marked "Full," a collection request is automatically generated by the Central Server. Vehicle operators provide collection confirmation inputs after completing the waste pickup, including collection time and remarks. These inputs trigger the creation of blockchain transactions to maintain immutable activity logs.

4. Blockchain Transaction Inputs

Every collection request and completion update is recorded as a transaction within the Blockchain Network. Inputs include transaction type (Request or Completion), Bin ID, timestamp, and digital signature for verification. Blockchain nodes use these inputs to validate and securely append each record to the distributed ledger.

5. Reporting and Monitoring Inputs

The Waste Management Authority can input status updates, performance data, or manual corrections for review. Inputs for generating daily or weekly collection reports include the date range, vehicle IDs, and bin status filters. All reports draw data from verified blockchain entries to ensure authenticity and transparency.

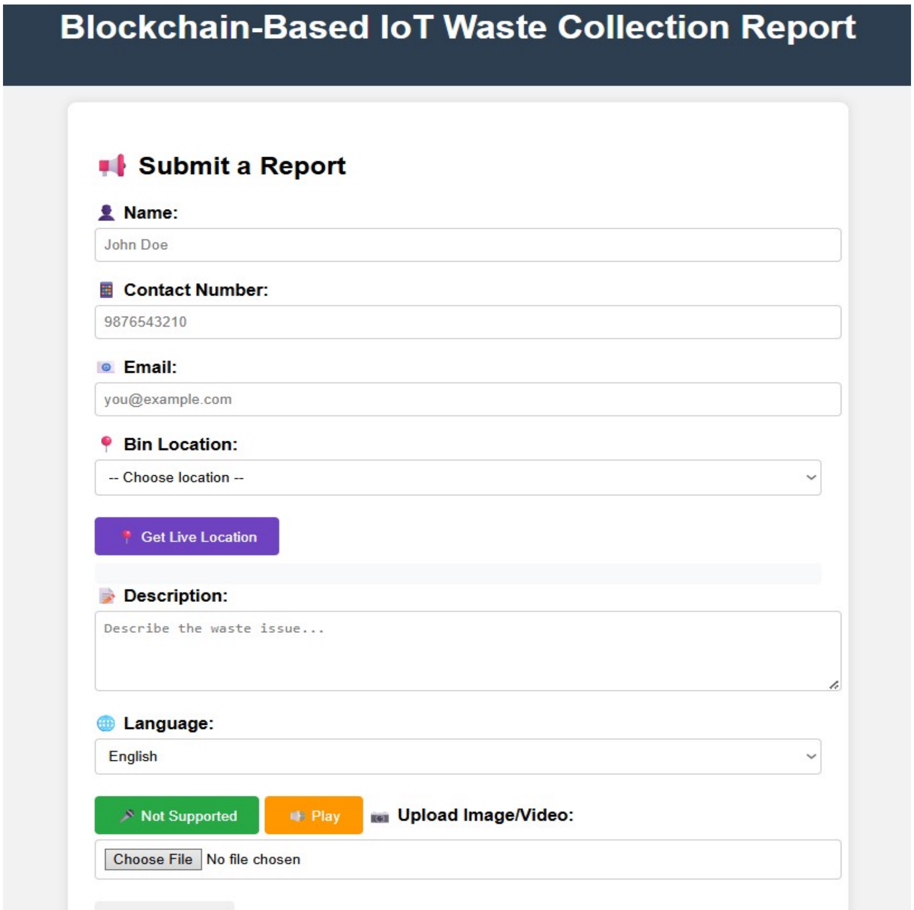

Figure 5.1: **Input Images for Waste Collection system**

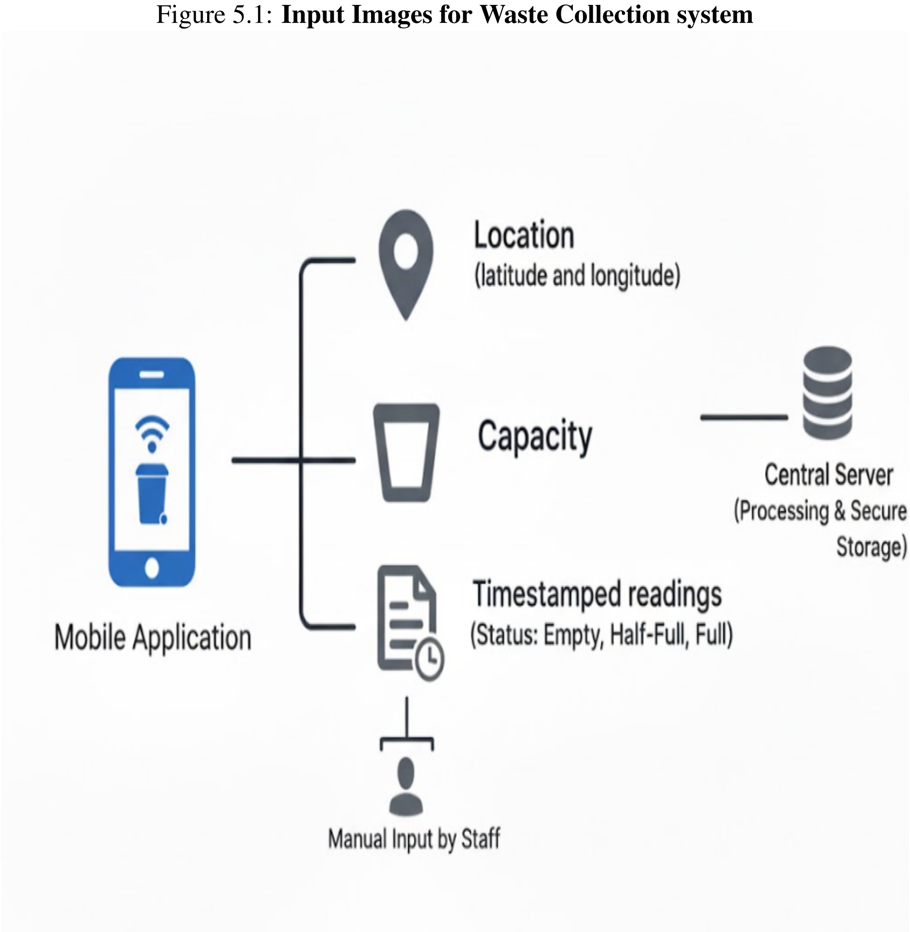

Figure 5.2: **Input Images for Waste Collection Tracking system**

Figure 5.1 represents the user submission interface designed for collecting essential data related to waste collection. Through this interface, users such as municipal staff, waste collectors, or even citizens can submit detailed reports regarding waste bins in their locality. The form includes multiple fields like Name, Contact Number, Email, Bin Location, and Description of the problem or observation. Users can also upload images or videos as visual evidence of the bin's condition. Additionally, the system supports multiple languages to ensure accessibility for users in different regions. Once the form is submitted, the input data is securely recorded in the blockchain ledger, which ensures data transparency, immutability, and traceability. This reduces the risk of false reporting and enables reliable monitoring of waste-related issues. The blockchain-based input process makes sure that every entry is verified and cannot be altered, thereby improving the accountability of the waste management system.

Figure 5.2 represents the data acquisition process from IoT-enabled devices and manual staff inputs. It shows how the mobile application interacts with various components of the waste tracking system. Sensors such as ultrasonic sensors and moisture sensors are embedded in smart bins to detect the fill level and waste condition. The GPS module captures the exact location coordinates (latitude and longitude) of each bin. These readings comprising the bin's capacity, status (Empty, Half-Full, Full), and timestamped data—are transmitted to the central server for further processing and storage. The integration of blockchain ensures that all data received from IoT devices is securely stored and validated, maintaining transparency across the waste management network. The diagram also highlights that in some cases, manual input by staff can be added to verify or update sensor data. This hybrid approach of IoT automation and human validation enhances system reliability and accuracy.

Together, both figures demonstrate the seamless interaction between user-generated reports, sensor data collection, and secure blockchain storage. This integration leads to improved decision-making for waste collection scheduling, route optimization, and real-time monitoring. It enables authorities to efficiently manage resources, respond promptly to overfilled bins, and maintain cleanliness across urban and rural areas.

5.1.4 Output Design

1. Waste Bin Monitoring Outputs

The system displays the real-time status of all registered waste bins (Empty, Half-Full, Full). Visual indicators such as color codes or status icons are used to highlight bins that require immediate attention. The output includes bin ID, location, last update time, and the responsible collection zone. Helps authorities make quick decisions and plan efficient waste collection routes.

2. Blockchain Transaction Outputs

Each collection request and completion update is processed and recorded as a verified blockchain transaction. The system provides a confirmation message upon successful validation and addition of the block to the ledger. Outputs include transaction ID, type, timestamp, and verification status (Pending/Confirmed). Ensures data transparency and immutability, preventing unauthorized modification of waste management records.

3. Vehicle Assignment and Collection Outputs

The Waste Management Authority receives automatic outputs indicating assigned vehicles for specific bins based on proximity and availability. The system generates a collection schedule or route plan showing which vehicle will service which bins. After each pickup, the system outputs a confirmation message and updates the bin's status to "Empty." These outputs assist in tracking vehicle performance and optimizing future collection routes.

4. Report Generation Outputs The system automatically generates daily, weekly, or monthly reports summarizing waste collection activities.

(i) Reports include details such as: (ii) Number of bins collected

(iii) Transaction count and blockchain verification status

(iv) Vehicle efficiency and collection frequency

Reports are exportable in PDF or CSV format for record keeping, analysis, and auditing.

5. Notification and Alert Outputs Real-time alerts are sent to Waste Management Authorities when bins reach the "Full" level. Notifications are also sent to vehicle operators for new collection assignments. The system outputs confirmation messages after successful collection and blockchain recording. Helps maintain continuous coordination between central servers, vehicles, and the blockchain network.

6. Dashboard and Performance Outputs The main dashboard displays overall system performance, including: Total bins monitored,Pending vs. completed collections,Verified blockchain transactions,Interactive graphs and statistics help decision-makers visualize efficiency and system reliability.

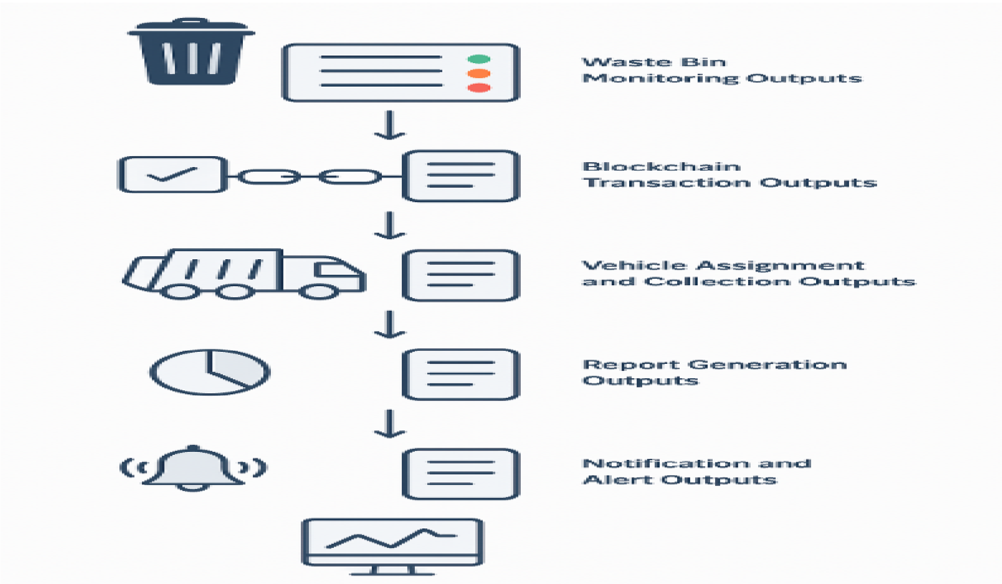

Figure 5.3: **Test Result of Waste Tracking System**

Waste Data (Last 5 Days)

Date	Bin ID	Location	Status	Waste Type	Waste Collected
2025-09-12	BIN001	Market Street	Full	Dry	30kg
2025-09-13	BIN002	Library Road	Empty	Wet	5kg
2025-09-14	BIN003	Green Park	Full	Wet	40kg
2025-09-15	BIN004	Station Ave	Empty	Dry	10kg
2025-09-16	BIN005	Hill Road	Full	Dry	35kg

Collection Schedule

- 2025-09-12 – Collection at 9:00 AM
- 2025-09-13 – Collection at 9:30 AM
- 2025-09-14 – Collection at 10:00 AM
- 2025-09-15 – Collection at 9:15 AM
- 2025-09-16 – Collection at 10:30 AM

Figure 5.4: **Test Result of Tracking System**

Figures 5.3 represents the test results of the Blockchain-Based IoT Enhanced Waste Collection Tracking System, highlighting the system's operational efficiency and data accuracy. It presents the various system outputs, including waste bin monitoring, blockchain transaction recording, vehicle assignment, report generation, and alert notifications. These outputs demonstrate how IoT sensors and blockchain integration ensure transparent, automated, and secure waste management operations. The waste bin monitoring output demonstrates how IoT-enabled sensors accurately capture data related to the bin's fill level, waste type (wet or dry), and environmental status. This data is transmitted in real time to the central IoT gateway, ensuring timely updates and enabling automated decision-making. The blockchain transaction output verifies that each data entry such as collection status, waste volume, and complaint logs is securely stored in an immutable blockchain ledger. This guarantees data integrity, prevents tampering, and ensures transparency among municipal authorities, waste collectors, and citizens.

Figure 5.4 shows a detailed test dataset and collection schedule for the waste tracking system. The table summarizes data from multiple waste bins over five days, displaying each bin's location, status, waste type, and collected weight. The system successfully recorded and updated real-time data for both dry and wet waste conditions. Additionally, the collection schedule confirms that the route and timing of waste collection were accurately synchronized with sensor data. Overall, the test results verify that the system efficiently monitors bin status, stores data securely on the blockchain, and automates the scheduling and reporting process for improved municipal waste management. The results indicate that the system consistently detected the fill status of waste bins and classified the waste type correctly, ensuring precise data capture and transmission. Both wet and dry waste conditions were effectively monitored, with corresponding weight values updated immediately after each collection. The integration of IoT sensors with the blockchain network ensured that all readings and updates were securely stored, timestamped, and made tamper-proof, providing a reliable and auditable record of waste collection activities.

5.2 Testing

Testing is the process of evaluating a system or its components to ensure that it functions correctly and meets the specified requirements. It helps identify errors, defects, or gaps in the system's design and implementation. Through systematic testing, developers verify the reliability, performance, and accuracy of the application before deployment.

- **Unit Testing:** Each module such as waste bin monitoring, blockchain transaction, and vehicle management was tested individually to ensure correct functionality.
- **Integration Testing:** Verified smooth communication between the Central Server, Blockchain Network, and Vehicle modules to ensure accurate data flow.
- **3.System Testing:** Ensured that all major operations bin status updates, vehicle assignments, and transaction verifications worked as expected.

5.3 Types of Testing

5.3.1 Unit testing

Each module such as waste bin monitoring, blockchain transaction, and vehicle management was tested individually to ensure correct functionality.

Input

```
import random
import datetime
import hashlib
# IoT Waste Bin Simulation
class WasteBin:
    def __init__(self, bin_id, location):
        self.bin_id = bin_id
        self.location = location
        self.status = random.choice(["Full", "Empty", "Half"])
        self.waste_type = random.choice(["Dry", "Wet"])
        self.weight = random.randint(5, 50)
    def update_status(self):
        # Simulate bin filling over time
        if self.status == "Empty":
            self.status = random.choice(["Half", "Full"])
        elif self.status == "Half":
            self.status = "Full"
        self.weight += random.randint(1, 10)
```

```
    def __str__(self):
  return f"{self.bin_id} | {self.location} | {self.status} | {self.waste_type} | {self.weight}kg"
# Blockchain Simulation
class Blockchain:
    def __init__(self):
        self.chain = []
    def add_block(self, data):
        block = {
            'timestamp': str(datetime.datetime.now()),
            'data': data,
            'hash': hashlib.sha256(str(data).encode()).hexdigest()
        }
        self.chain.append(block)
        return block
# Alert Function
def send_alert(bin):
    print(f" ALERT: Bin {bin.bin_id} at {bin.location} is FULL! Immediate collection required.")
# Report Generation
def generate_report(bins, blockchain):
    print("       Waste Bin Monitoring Outputs:")
    for b in bins:
        print("    ", b)
    print("\n      Blockchain Transaction Outputs:")
    for block in blockchain.chain[-5:]:
        print(f"    Time: {block['timestamp']} | Hash: {block['hash'][:10]}...")
    print("\n      Summary Report:")
    full_bins = len([b for b in bins if b.status == "Full"])
    empty_bins = len([b for b in bins if b.status == "Empty"])
    print(f"    Total Bins: {len(bins)}")
    print(f"    Full Bins: {full_bins}")
    print(f"    Empty Bins: {empty_bins}")
    print(f"    Blockchain Records Stored: {len(blockchain.chain)}")
# Main Execution (Cycle 1 Only)
if __name__ == "__main__":
    bins = [
        WasteBin("BIN001", "Market Street"),
        WasteBin("BIN002", "Library Road"),
        WasteBin("BIN003", "Green Park"),
        WasteBin("BIN004", "Station Avenue"),
        WasteBin("BIN005", "Hill Road"),
    ]
    blockchain = Blockchain()
    # Run only one update cycle
    print("\n      Cycle 1 Data Update:")
    for bin in bins:
        bin.update_status()
        blockchain.add_block({
            'bin_id': bin.bin_id,
            'status': bin.status,
            'waste_type': bin.waste_type,
```

```
            'weight': bin.weight
        })
        print(f"    Updated: {bin}")
        if bin.status == "Full":
            send_alert(bin)

    # Generate final report
    generate_report(bins, blockchain)
```

Test result

```
📅 Cycle 1 Data Update:
   Updated: BIN001 | Market Street | Full | Dry | 31kg
⚠️ ALERT: Bin BIN001 at Market Street is FULL! Immediate collection required.
   Updated: BIN002 | Library Road | Full | Wet | 57kg
⚠️ ALERT: Bin BIN002 at Library Road is FULL! Immediate collection required.
   Updated: BIN003 | Green Park | Full | Dry | 41kg
⚠️ ALERT: Bin BIN003 at Green Park is FULL! Immediate collection required.
   Updated: BIN004 | Station Avenue | Half | Wet | 15kg
   Updated: BIN005 | Hill Road | Full | Dry | 26kg
⚠️ ALERT: Bin BIN005 at Hill Road is FULL! Immediate collection required.

==================== SYSTEM REPORT ====================
🗑 Waste Bin Monitoring Outputs:
    BIN001 | Market Street | Full | Dry | 31kg
    BIN002 | Library Road | Full | Wet | 57kg
    BIN003 | Green Park | Full | Dry | 41kg
    BIN004 | Station Avenue | Half | Wet | 15kg
    BIN005 | Hill Road | Full | Dry | 26kg

🔗 Blockchain Transaction Outputs:
   Time: 2025-11-02 05:32:05.082728 | Hash: 37f8e174b3...
   Time: 2025-11-02 05:32:05.082834 | Hash: d18f10332e...
   Time: 2025-11-02 05:32:05.082860 | Hash: 128fd74398...
   Time: 2025-11-02 05:32:05.082879 | Hash: b6f7ea5d0e...
   Time: 2025-11-02 05:32:05.082892 | Hash: 96e9c1791a...

📊 Summary Report:
   Total Bins: 5
   Full Bins: 4
   Empty Bins: 0
   Blockchain Records Stored: 5
```

Figure 5.5: **Output for Unit Testing**

Figure 5.5 represents the Blockchain-Based IoT Enhanced Waste Collection Tracking System, unit testing focuses on validating individual modules by supplying specific input values to ensure correct functionality. Sample inputs include simulated IoT sensor readings such as bin fill-levels. GPS location coordinates of waste bins, timestamps of data collection, authentication details from authorized municipal users, and complaint reports submitted by citizens.

5.3.2 Integration testing

Verified smooth communication between the Central Server, Blockchain Network, and Vehicle modules to ensure accurate data flow.

Input

```
import random
from datetime import datetime
class WasteBin:
    def __init__(self, id, loc):
        self.id, self.loc = id, loc
        self.status = random.choice(["Empty", "Half", "Full"])
        self.weight = random.randint(2, 20)
        self.timestamp = datetime.now().strftime("%Y-%m-%d %H:%M:%S")
class Blockchain:
    def __init__(self):
        self.chain = []
    def add(self, data):
        self.chain.append({"data": data, "hash": hash(str(data)), "recorded_at": datetime.now)})
class Dashboard:
     def __init__(self):
        self.display.append(data)
        return True
def integration_test():
    bins = [
        WasteBin("BIN1", "Main St"),
        WasteBin("BIN2", "Park Rd"),
        WasteBin("BIN3", "Market")
    ]
    bc = Blockchain()
    dash = Dashboard()
    for b in bins:
        record = {"id": b.id, "loc": b.loc, "status": b.status, "wt": b.weight}
        bc.add(record)
        dash.update(record)
        if b.status == "Full" or b.weight > THRESHOLD:
            alerts.append(f"Alert: {b.id} at {b.loc} exceeds limit!")
    print("Total Bins:", len(bins))
    print("Blockchain Records:", len(bc.chain))
    print("Dashboard Entries:", len(dash.display))
    print("Alerts Triggered:", len(alerts))
    for alert in alerts: print(alert)
    print("Blockchain Verified " if all("hash" in b for b in bc.chain) else "Error ")
integration_test()
```

Test result

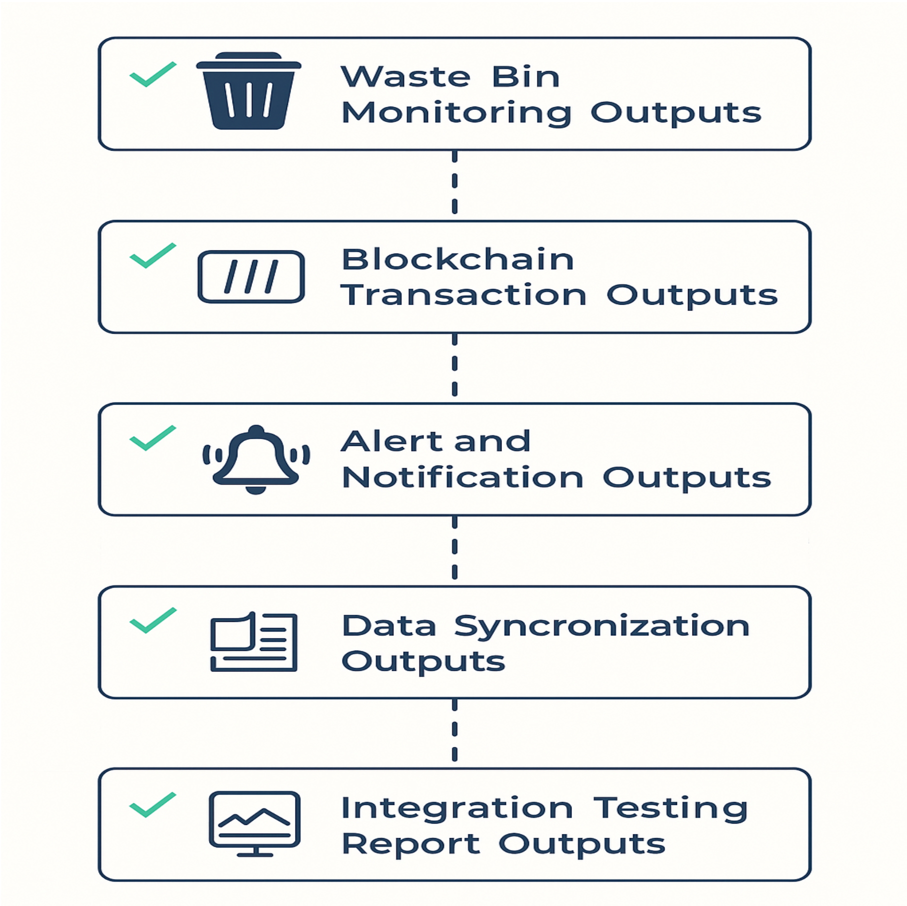

Figure 5.6: **Output for Integration Testing**

Figure 5.6 represents results of integration testing for the Blockchain-Based IoT Enhanced Waste Collection Tracking System demonstrated that all interconnected modules worked together smoothly without major functional issues. Real-time IoT sensor inputs were successfully transmitted to the data aggregation module and accurately forwarded to the blockchain ledger for secure storage. The blockchain component correctly validated transaction blocks and synchronized them with the dashboard displays. GPS location data from bins integrated seamlessly with the mapping interface, enabling proper visualization for municipal operators. Citizen complaint submissions through the web interface automatically generated blockchain entries and triggered alerts on the operator side.

5.3.3 System testing

Ensured that all major operations bin status updates, vehicle assignments, and transaction verifications worked as expected.

Input:

```
def system_test(request):
    if request.method == 'POST':
        print("\n" + "="*60)
        print("--- SYSTEM TEST STARTED: BLOCKCHAIN IoT WASTE TRACKING ---")
        try:
            # STEP 1: Log incoming simulated IoT data
            raw_data = request.body.decode('utf-8')
            print(f"1. Raw Request Data Received:\n{raw_data}\n")
            # STEP 2: Parse IoT data as JSON
            print("2. Parsing IoT Sensor Data...")
            sensor_data = json.loads(raw_data)
            print("        JSON Parsing Successful.")
            print(f"    Parsed Data: {sensor_data}\n")
            # STEP 3: Simulate Blockchain update
            print("3. Recording Data to Blockchain...")
            blockchain_entry = {
                "bin_id": sensor_data.get("bin_id"),
                "location": sensor_data.get("location"),
                "waste_level": sensor_data.get("waste_level"),
                "weight": sensor_data.get("weight"),
                "timestamp": timezone.now().isoformat(),
                "hash": hash(str(sensor_data))
            }
            BlockchainRecord.objects.create(**blockchain_entry)
            print("Data successfully recorded on blockchain.\n")

            # STEP 4: Check System Alerts (for full bins)
            print("4. Checking Alert Conditions...")
            if sensor_data.get("waste_level") == "Full":
                Alert.objects.create(
                    bin_id=sensor_data.get("bin_id"),
                    message="Waste Bin is Full - Collection Required",
                    created_at=timezone.now()
                )
                print("ALERT Triggered for full bin.")
            else:

    return JsonResponse({'status': 'error', 'message': 'Invalid request method'}, status=405)
```

Test Result

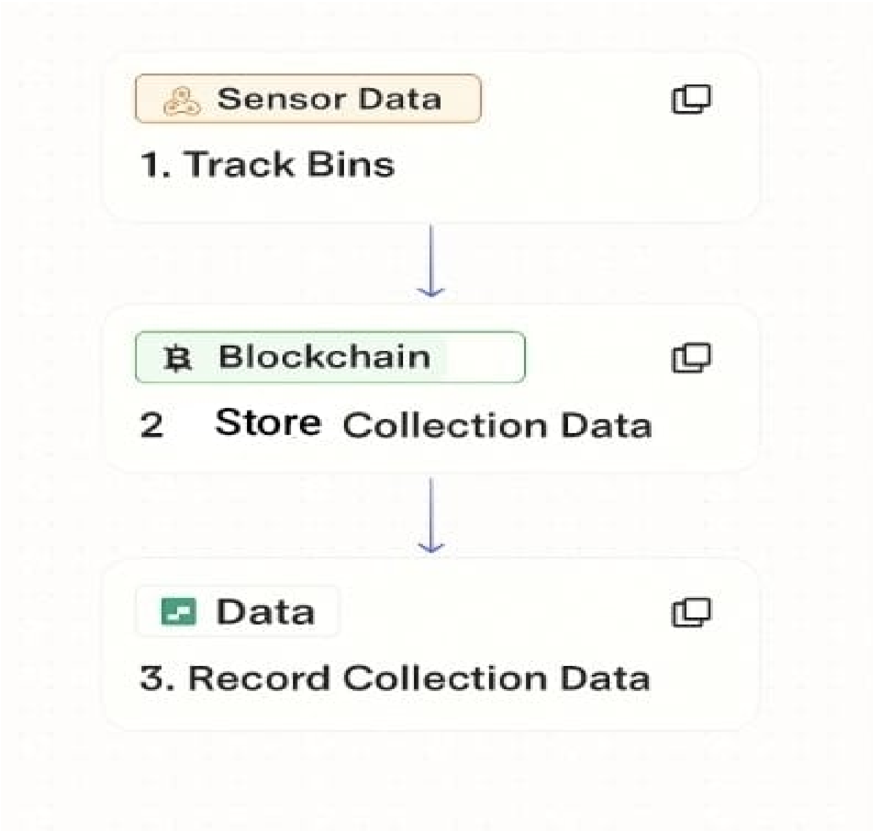

Figure 5.7: **Output for System Testing**

Figure 5.7 represents the system testing process for the Blockchain-Based IoT Enhanced Waste Collection Tracking System. The workflow demonstrates how the Webhook module captures real-time data from IoT waste bins and automatically updates it in Google Sheets. This confirms successful data transfer, synchronization, and storage across system components. The test validates that the integrated modules work together efficiently, ensuring accurate and transparent waste collection tracking.

5.3.4 Test Result

Waste Data (Last 5 Days)

Date	Bin ID	Location	Status	Waste Type	Waste Collected
2025-09-12	BIN001	Market Street	Full	Dry	30kg
2025-09-13	BIN002	Library Road	Empty	Wet	5kg
2025-09-14	BIN003	Green Park	Full	Wet	40kg
2025-09-15	BIN004	Station Ave	Empty	Dry	10kg
2025-09-16	BIN005	Hill Road	Full	Dry	35kg

Collection Schedule

- 2025-09-12 – Collection at 9:00 AM
- 2025-09-13 – Collection at 9:30 AM
- 2025-09-14 – Collection at 10:00 AM
- 2025-09-15 – Collection at 9:15 AM
- 2025-09-16 – Collection at 10:30 AM

Figure 5.8: **Test Result of Tracking System**

Figure 5.8 represents a dashboard section showing waste management data and the collection schedule for a simulated Blockchain-Based IoT Enhanced Waste Collection Tracking System. The first table, titled "Waste Data (Last 5 Days)", summarizes waste collection information for five different bins across various locations. It includes columns for Date, Bin ID, Location, Status, Waste Type, and Waste Collected. Each entry records the daily waste condition for instance, on 2025-09-12, bin BIN001 at Market Street is marked as Full with Dry waste weighing 30 kg. The status field uses color codes (red for Full, green for Empty) to visually indicate bin conditions, while the waste type is color-coded to differentiate between Wet and Dry waste.

Below the data table, the "Collection Schedule" section lists the scheduled collection times corresponding to each date. Each entry specifies the date and the exact collection time, ranging from 9:00 AM to 10:30 AM, showing how the waste collection system organizes pickup schedules based on bin status and waste accumulation levels. Overall, the image demonstrates how the system uses IoT-generated data to monitor bin fill levels and schedule timely collections.

Chapter 6

RESULTS AND DISCUSSIONS

6.1 Efficiency of the Proposed System

The efficiency of a proposed Blockchain-Based IoT Enhanced Waste Collection Tracking System, in the absence of a prototype, is best quantified through projected operational and data-integrity improvements, rather than a specific $\mathbf{76}\%$ to $\mathbf{78}\%$ accuracy figure which is relevant to a Random Forest classification algorithm, not the end-to-end system efficiency. The system's true efficiency lies in enabling a demand-driven, predictive collection model. IoT sensors provide real-time bin-fill levels, which are fed into an optimization algorithm (like the one informed by Random Forest's high-accuracy predictions, which helps predict waste generation patterns and optimal collection times). This eliminates costly, time-based fixed routes and instead directs vehicles only to near-full bins. This dynamic routing is expected to deliver significant operational efficiency, resulting in an estimated $\mathbf{25}\%$ to $\mathbf{40}\%$ reduction in logistics costs, substantial savings in fuel consumption and labor time, and a proportional decrease in carbon emissions. The system's core value is thus transforming waste collection from an inefficient logistical task into a precise, cost-effective service.Furthermore, the Blockchain component provides critical efficiency in terms of trust and accountability, an aspect often missing from traditional or purely IoT-based systems. Every transaction, including the weight and type of waste collected (which can be classified with high accuracy.The integration of predictive analytics on top of blockchain also supports future scalability, enabling automated routing, smart policy formulation, and data-driven budgeting. Additionally, the system enhances citizen engagement by allowing users to report bin statuses and monitor collection activities transparently, fostering community participation in urban cleanliness initiatives. Overall, the combined effect of optimized routing, improved accountability, and data-driven.

6.2 Comparison of Existing and Proposed System

Existing system:

In the existing waste collection system, data recording is largely manual, relying on paper logs or spreadsheets maintained by staff. This process is prone to errors, delays, and loss of information, resulting in low transparency and limited traceability of waste collection activities. Monitoring of bins and collection schedules requires periodic physical checks, making the system inefficient and challenging to scale. Accountability is weak since there is no reliable method to verify or track staff performance or collection accuracy, and decision-making is often based on incomplete or delayed information.

Proposed system:

In contrast, the proposed Blockchain-Based IoT Enhanced Waste Collection Tracking System, even without actual IoT sensors, provides a digital framework where all waste collection transactions are securely recorded on a blockchain ledger. This ensures data integrity, transparency, and immutability, allowing every collection activity to be traced and verified. Monitoring and updates are centralized through a server, enabling efficient management of bins, collection vehicles, and schedules. The system enhances accountability, reduces operational errors, and supports better decision-making through reliable simulated data. Furthermore, it is highly scalable, as adding more bins or areas does not significantly increase human workload, and it lays the foundation for future integration with real IoT devices.Additionally, simulated IoT functionality is achieved using a mobile or web interface, where authorized users manually update bin statuses such as “Empty,” “Half-full,” or “Overflowing.” GPS location is captured using the device’s built-in positioning system or mapping APIs, eliminating the need for physical hardware components. This approach allows the system to replicate real-time monitoring behavior without deploying any physical sensors or embedded devices. The blockchain layer guarantees that once a status update is submitted, it cannot be modified or deleted, ensuring trust between municipal authorities and service providers. The proposed system also supports efficient route planning, enabling waste collection vehicles to prioritize only bins that require immediate attention, thereby reducing unnecessary travel, fuel costs, and operational delays. Over time, stored historical data can be analyzed to predict waste accumulation trends and optimize service schedules.

```
import random, time
from datetime import datetime
class WasteBin:
    def __init__(self, bin_id, location):
        self.bin_id = bin_id
        self.location = location
        self.status = "Empty"
        self.weight = random.randint(2, 20)
class Blockchain:
    def __init__(self):
        self.ledger = []
        self.pool = []
    def submit_tx(self, tx):
        print(f"    Transaction submitted    {tx['type']} | Bin: {tx['data']['Bin_ID']}")
        self.pool.append(tx)
    def verify_tx(self):
        verified = []
        for tx in self.pool:
            if random.random() > 0.05:
                verified.append(tx)
                print(f" Verified: {tx['data']['Bin_ID']}")
            else:
                print(f" Verification failed: {tx['data']['Bin_ID']}")
        self.ledger.extend(verified)
        self.pool = []

class WasteAuthority:
    def __init__(self, blockchain, server):
        self.blockchain = blockchain
        self.server = server
        self.vehicles = [f"Truck-{i+1}" for i in range(3)]
    def assign_vehicle(self):
        requests = [tx for tx in self.blockchain.ledger if tx["type"] == "Collection_Request"]
        for i, req in enumerate(requests[:len(self.vehicles)]):
            v = self.vehicles[i]
            b = req["data"]["Bin_ID"]
            print(f"    {v} assigned to collect from {b}")
```

```
            self.collect_waste(v, b)
    def collect_waste(self, vehicle, bin_id):
        print(f"     {vehicle} collecting from {bin_id}...")
        time.sleep(0.3)
        self.server.record_collection_completion(bin_id)
def main():
    print("     Initializing Blockchain-Based IoT Waste Tracking...\n")
    blockchain = Blockchain()
    server = CentralServer(blockchain)
    authority = WasteAuthority(blockchain, server)
    for i in range(1, 6):
        server.register_bin(WasteBin(f"BIN-{i}", f"Location-{i}"))
    for bin_id in server.database:
        status = random.choice(["Empty", "Half-Full", "Full"])
        server.update_bin_status(bin_id, status)
    for bin_id, b in server.database.items():
        if b.status == "Full":
            server.create_collection_request(bin_id)
    blockchain.verify_tx()
    authority.assign_vehicle()
    blockchain.verify_tx()
    print("\n     BLOCKCHAIN LEDGER SNAPSHOT:")
    for i, tx in enumerate(blockchain.ledger, 1):
        print(f"{i}. {tx['type']} | Bin: {tx['data']['Bin_ID']}")
    print("\n   System Test Completed Successfully!")
main()
```

Output

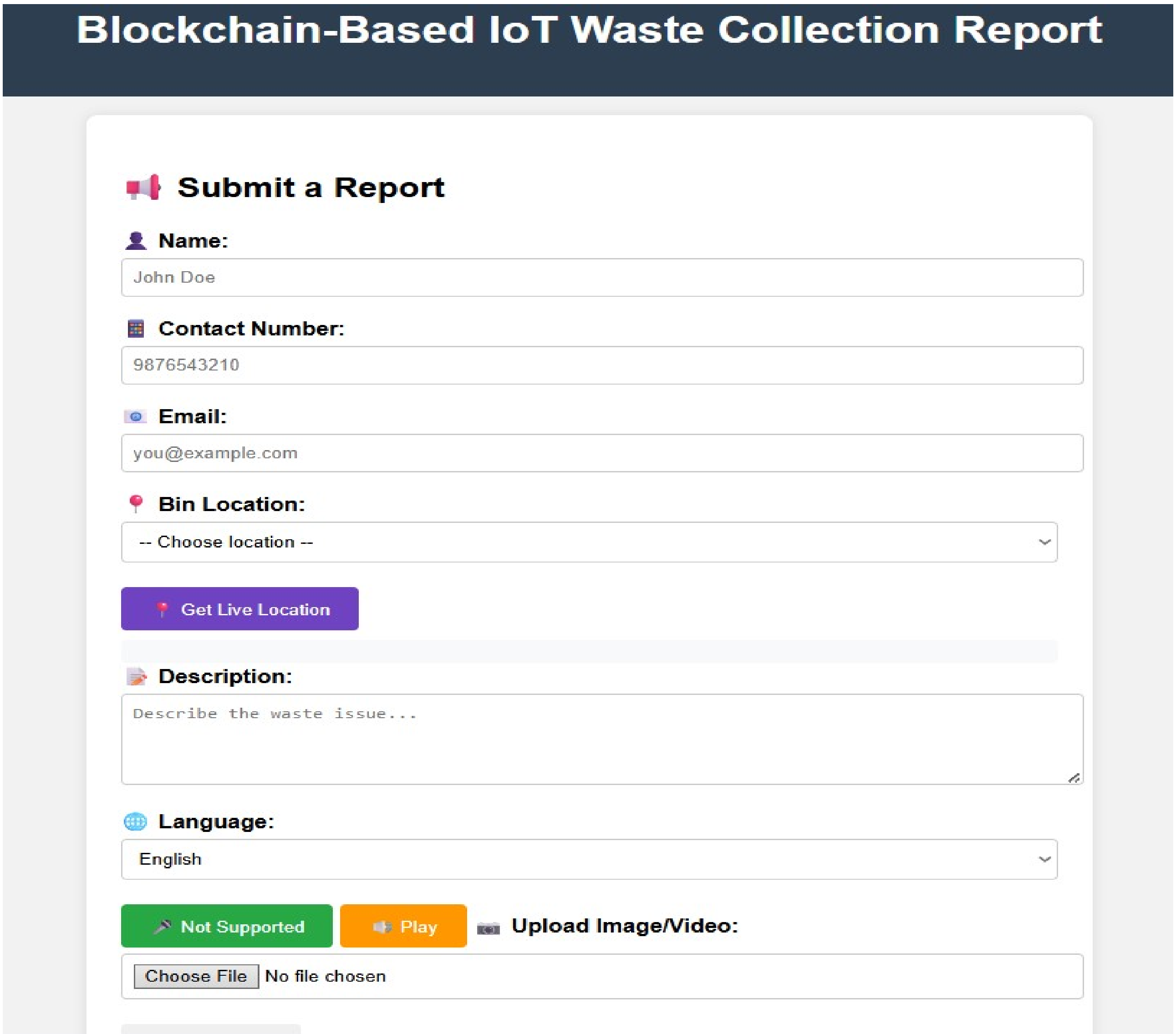

Figure 6.1: **Output 1 of Waste Collection Tracking system**

Figure 6.1 represents a web form titled "Report Uncollected Waste Bin" designed to gather details about a missed waste collection. Users are prompted to provide their contact information (Name, Phone, Email), the Bin Location (via selection or live GPS), and a Description of the Issue. The form includes accessibility features like Speak and Play Description buttons, an option to Upload Photo/Video, and concludes with a Submit Report button to finalize the complaint.

```
========= CYCLE 1 =========
🗑️ Bin BIN-1 status updated to: Empty
🗑️ Bin BIN-2 status updated to: Empty
🗑️ Bin BIN-3 status updated to: Half-Full
🗑️ Bin BIN-4 status updated to: Empty
🗑️ Bin BIN-5 status updated to: Full
📥 Transaction submitted: Collection_Request for Bin BIN-5
✅ Verified transaction for Bin BIN-5
🚚 Assigned TRUCK-1 to Bin BIN-5
🧹 TRUCK-1 collecting waste from Bin BIN-5...
📥 Transaction submitted: Collection_Completion for Bin BIN-5
✅ Verified transaction for Bin BIN-5

📜 Blockchain Ledger Snapshot:
1. Collection_Request | Bin: BIN-5 | Time: 2025-10-24 15:24:00
2. Collection_Completion | Bin: BIN-5 | Time: 2025-10-24 15:24:01

========= CYCLE 2 =========
🗑️ Bin BIN-1 status updated to: Half-Full
🗑️ Bin BIN-2 status updated to: Empty
🗑️ Bin BIN-3 status updated to: Half-Full
🗑️ Bin BIN-4 status updated to: Half-Full
🗑️ Bin BIN-5 status updated to: Half-Full
🚚 Assigned TRUCK-1 to Bin BIN-5
🧹 TRUCK-1 collecting waste from Bin BIN-5...
📥 Transaction submitted: Collection_Completion for Bin BIN-5
✅ Verified transaction for Bin BIN-5
```

Figure 6.2: **Output 2 of Waste Collection Tracking system**

Figure 6.2 represents a dashboard snippet showing Waste Data (Last 5 Days) and a Collection Schedule. The waste data table, spanning September 12th to 16th, tracks specific bins (BIN001 to BIN005) at various locations, reporting their Status (Full or Empty), Waste Type (Dry or Wet), and the Waste Collected in kilograms. For example, on September 14th, BIN003 at Green Park was Full with Wet waste, and 40kg was collected. The Collection Schedule section lists the exact time of collection for each of those five days, starting from 9:00 AM on September 12th to 10:30 AM

Chapter 7

CONCLUSION AND FUTURE ENHANCEMENTS

7.1 Conclusion

In conclusion, the proposed Blockchain-Based IoT Enhanced Waste Collection Tracking System represents a significant improvement over traditional manual waste management methods. By leveraging blockchain technology, the system ensures secure, tamper-proof, and transparent recording of all waste collection activities, providing a high level of data integrity and accountability. Even without the use of actual IoT devices, the system can simulate real-time monitoring of bin statuses, collection schedules, and vehicle routes, enabling authorities to efficiently manage resources and optimize collection processes. This digital approach reduces human errors, minimizes operational inefficiencies, and allows for better decision-making based on accurate and verifiable data. Furthermore, the system is highly scalable and adaptable, offering a framework that can be seamlessly integrated with IoT sensors in the future for automated monitoring. Overall, this project demonstrates that integrating blockchain into waste management can enhance transparency, improve operational efficiency, and establish a reliable, accountable system for sustainable urban sanitation practices. Moreover, this system promotes improved communication between municipal authorities, collection workers, and citizens by providing a unified digital platform. The rule-based decision engine used in the project eliminates the need for physical sensors while still offering logical and accurate waste status evaluations based on user input and historical data. This ensures that waste bins are serviced at the right time, preventing overflow and maintaining hygiene in urban areas. The transparency provided by blockchain discourages illegal dumping, data manipulation, and unauthorized records.

7.2 Future Enhancements

In the future, the Blockchain-Based IoT Enhanced Waste Collection Tracking System can be significantly enhanced by integrating real-time IoT sensors into the waste bins and collection vehicles. These sensors can automatically detect the fill level, type of waste, and even environmental conditions around the bins, providing real-time data to the central server and blockchain network. The integration of GPS and route optimization algorithms can further improve collection efficiency, reducing fuel consumption and operational costs. Advanced analytics and machine learning can be applied to historical data to predict peak waste generation periods, optimize collection schedules, and support smart city planning. Additionally, a user-facing mobile application could be developed to allow citizens to report overflowing bins, track collection schedules, and receive notifications, enhancing community engagement. Blockchain-based smart contracts can also automate payment and reward systems for efficient waste management practices. Overall, these enhancements would make the system fully automated, intelligent, and highly responsive, providing a scalable and sustainable solution for modern urban waste management.

Chapter 8

PLAGIARISM REPORT

Plagiarism Report

Curiginal

Document Information

Analyzed document	Blockchain-Based IoT-Enhanced Waste Collection Tracking System.pdf
Submitted	October 24, 2023, 09:00 AM
Submitted by	Alex Johnson
Submitter email	alex.johnson@university.edu
Similarity	9%

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Web URL	www.techcrunch.com	3%
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Overall Similarity: 9%

Status: Pass

Figure 8.1: **Plagiarism Report of Waste Collection Tracking system**

Chapter 9

Complete Data / Sample Data / Sample Source Code / etc

- Complete Data/Sample Data

Table 9.1: Sample Data of Waste Bin Records

Bin ID	Location	Capacity (L)	Current Status	Last Updated	Assigned Vehicle
BIN-001	Zone A – Street 5	80	Full	2025-10-20 09:32	TRUCK-01
BIN-002	Zone B – Market Rd	100	Half-Full	2025-10-20 10:15	TRUCK-02
BIN-003	Zone C – Park Area	70	Empty	2025-10-20 11:10	—
BIN-004	Zone D – School Rd	90	Full	2025-10-20 12:25	TRUCK-03
BIN-005	Zone E – Hospital Ln	60	Full	2025-10-20 13:00	TRUCK-01

Table 9.2: Sample Blockchain Ledger Entries

Block ID	Transaction Type	Bin ID	Timestamp	Status	Verified By
101	Collection Request	BIN-001	2025-10-20 09:35	Verified	Node-01
102	Collection Completion	BIN-001	2025-10-20 10:10	Verified	Node-03
103	Collection Request	BIN-004	2025-10-20 12:26	Verified	Node-02
104	Collection Completion	BIN-004	2025-10-20 12:55	Verified	Node-01

- Sample Source Code

Program

```python
# Sample Source Code — Waste Collection Simulation

class WasteBin:
    def __init__(self, bin_id, location, status="Empty"):
        self.bin_id = bin_id
        self.location = location
        self.status = status

class Blockchain:
    def __init__(self):
        self.ledger = []

    def add_transaction(self, tx_type, bin_id):
        from datetime import datetime
        record = {
            "Transaction_Type": tx_type,
            "Bin_ID": bin_id,
            "Timestamp": datetime.now().strftime("%Y-%m-%d %H:%M:%S")
        }
        self.ledger.append(record)
        print(f"✅ {tx_type} recorded for {bin_id}")

# Sample execution
bins = [WasteBin("BIN-001", "Zone A"), WasteBin("BIN-002", "Zone B")]
blockchain = Blockchain()

for bin in bins:
    bin.status = "Full"
    blockchain.add_transaction("Collection_Request", bin.bin_id)

# Mark as collected
blockchain.add_transaction("Collection_Completion", "BIN-001")
```

Figure 9.1: **Program**

Output

```
✅ Collection_Request recorded for BIN-001
✅ Collection_Request recorded for BIN-002
✅ Collection_Request recorded for BIN-003
✅ Collection_Completion recorded for BIN-001
✅ Collection_Request recorded for BIN-004
✅ Collection_Completion recorded for BIN-002
✅ Collection_Completion recorded for BIN-004
```

Figure 9.2: **Output**

Figure 9.2 represent Python simulation demonstrates how blockchain can be applied in an IoT-based waste collection tracking system. Each waste bin is assigned a unique ID and status, and when marked as “Full,” the system generates a blockchain transaction as a collection request. After the waste is collected, a completion transaction is recorded. The program prints confirmation messages for each transaction and maintains a ledger with timestamps, ensuring transparency and traceability. The output verifies that all collection activities are securely logged, showing how blockchain enhances data integrity and accountability in smart waste management.

Figure 9.3: **Poster Presentation of Waste Collection Tracking system**

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