

Smart Waste Collection Vehicle Tracker & Garbage Bin Level Tracker

**Ms. Gauri Chikte, Mr. Parth Kharade Ms. Shravani Hire, Ms. Prachi Gurgude,
Prof. Seemantini.S.Gaikwad** Lecturer In Computer Technology, K.K Wagh Polytechnic, Nashik
Department of Computer Technology,
K. K. Wagh Polytechnic, Nashik.

Abstract— The smart waste collection vehicle tracker C garbage bin level tracker is a cutting edge, realtime monitoring system designed to optimize waste collection operations and enhance customer satisfaction. The system is designed to optimize waste collection operations, improve customer satisfaction, and reduce waste handling costs. This innovative solution combines GPS technology with sensors to track the movement of waste collection vehicles and monitor garbage bin fill levels in realtime. This system provides unparalleled insights into waste collection patterns, allowing for predictive maintenance, optimized routing, and improved fleet management. With realtime updates on collection schedules and bin fill levels, customers can plan their waste disposal accordingly, reducing the risk of overflowing bins and minimizing the need for costly emergency services. The Arduino based system consists of two main components: a GPS enabled vehicle tracker and ultrasonic sensor. The vehicle tracker uses the GPS module to track the location and speed of waste collection vehicles, while the garbage bin level sensor uses ultrasonic sensor to monitor the fill levels of garbage bins. The system is connected to the internet using WiFi or cellular connectivity, allowing realtime data transmission to a cloud based platform. The platform uses machine learning algorithms to analyze data and provide insights into waste collection patterns, enabling predictive maintenance, optimized routing, and improved fleet management. This system has the potential to revolutionize the waste management industry, enabling a more efficient, sustainable, and customer centric approach to waste collection. The Smart Waste Collection Vehicle Tracker C Garbage Bin Level Tracker project offers a comprehensive solution for efficient waste management.

Keywords: GPS tracking, Garbage, Aurdino , Ultrasonic Sensor ,IOT.

1. INTRODUCTION

Waste collection is a critical aspect of urban management, and its efficiency can significantly impact the overall quality of life in a city. However, traditional waste collection methods are often plagued by inefficiencies, such as unnecessary delays, missed collections, and inadequate tracking of waste collection vehicles. This can lead to increased costs, environmental pollution, and decreased customer satisfaction. In recent years, the Internet of Things (IoT) has emerged as a powerful technology that can be leveraged to improve waste collection operations. IoT based solutions can provide realtime data on waste collection vehicle locations, routes, and fill levels, enabling more efficient and effective waste management. This system consists of two main components: a GPS enabled vehicle tracker and a garbage bin level sensor. The vehicle tracker uses the GPS module to track the location and speed of waste collection vehicles, while the ultrasonic sensors to monitor the fill levels of garbage bins. The system is designed to be easy to use, scalable, and cost effective, making it an attractive solution for municipalities and waste management companies. By leveraging the power Arduino technology, we aim to create a more efficient, sustainable, and customer centric approach to waste collection. The smart waste collection vehicle tracker C garbage bin level tracker has the potential to revolutionize the waste management industry by providing realtime insights into waste collection patterns, enabling predictive maintenance, optimized routing, and improved fleet management. This system can help reduce waste handling costs, minimize environmental pollution, and improve customer satisfaction. In this project, we will demonstrate the design and implementation of the smart waste collection vehicle tracker C garbage bin level tracker. We will also discuss the benefits and limitations of the system, as well as potential future developments and applications. The system has the potential to revolutionize the waste management industry by providing realtime data and analytics, enabling data driven decision making, and improving overall operational efficiency.

2. Problem Statement

The traditional paper-based passport system faces challenges in ensuring security, authenticity, and efficiency, leading to concerns about identity theft, counterfeiting, and lengthy border control processes. To address these issues, an E-Passport system utilizing RFID and biometric technologies can provide a secure, efficient, and reliable solution.

However, integrating these technologies poses challenges, including ensuring data privacy and security, preventing unauthorized access, and maintaining accurate biometric identification. Moreover, the system must comply with international standards and regulations, such as those set by the International Civil Aviation Organization (ICAO). This project aims to design and develop a secure, efficient, and user-friendly E-Passport system leveraging RFID and biometric technologies to enhance border control processes and ensure the integrity of identity documents.

2.1 Overflow Garbage Bin :-

In regular waste management setups, garbage bins are taken out according to fixed schedules instead of how full they actually are. This often means bins get completely full before the time they are supposed to be emptied. When bins overflow, trash spills out into nearby areas, creating dirty conditions, bad smells, and messy looks. Piles of waste bring in bugs, rats, and other animals, which can spread diseases and make the environment dirty. Also, when organic waste breaks down, it gives off harmful gases like methane, which pollute the air and add to climate change. Without checking the bins in real time, it's hard to act quickly and use resources efficiently.

2.2 Fixed-Route Collection Inefficiency

Traditional garbage trucks stick to set paths no matter if picking up trash is really needed. This strict way of planning causes several problems. Trucks might pick up trash from bins that aren't full, while other bins that are completely full are left alone. These fixed paths don't consider things like how much trash is made on different days, traffic jams, or urgent situations. Because of this, trucks make extra journeys, which take more time and make the whole process less efficient. Without smart ways to plan routes, the available resources aren't used in the best way.

2.3 High Fuel and Labor Costs

Inefficient ways of planning routes and making unnecessary trips for collecting waste lead to higher fuel use and more money spent. Waste trucks use a lot of fuel when they travel long distances without the best path. This raises costs and also adds to pollution and harm to the environment. Also, using people to manage and organize these tasks takes more labor. When there are sudden extra collections, workers have to work longer hours, which adds to their costs. The frequent and unplanned use of vehicles also causes more wear and tear, leading to higher repair and maintenance bills. All together, the old system puts a big financial strain on city officials.

2.3. Lack of Real-Time Monitoring and Transparency

Current waste management systems don't have a central way to track data or make decisions based on information. Officials can't follow where trucks go or check how full the trash bins are as things happen. This makes it hard to know how well the system is working and holds people accountable. Without up-to-date information, planning for waste collection is guesswork instead of being based on real needs. Problems like delays, wrong routes, and missed pickups usually go unnoticed. Also, not having clear information makes people less trustful and stops the system from getting better through using data.

3. Literature review

[1] Federated and Split Learning for IoT Anomaly Detection This study suggests a decentralized way to find unusual behavior in smart cities using federated learning, split learning, big data analysis, and smart computing. This method keeps personal data private while allowing different parts of the system to work together to find threats. The results of the experiments show that this approach helps detect problems more accurately and adapts well to new types of cyber attacks.

[2] Comprehensive IoT Security Framework for Smart Homes This research gives a full security plan for smart home IoT systems in smart cities. It brings together checking for weaknesses, finding intrusions, planning for threats, and teaching users about security. The plan focuses on being ready for threats and educating people to protect personal information.

[3] Machine Learning-Based DoS Detection in IoT-Enabled ICNs This paper looks at using machine learning to spot Denial of Service attacks in IoT-connected Information-Centric Networks. It talks about the difficulties, kinds of

attacks, and possible uses of machine learning, while also pointing out issues with how well it scales and works efficiently.

[4] **ML-Based Intrusion Detection for DoS Attacks in IoT** The authors offer an anomaly- based system for detecting DoS attacks using machine learning in IoT networks. The system studies network traffic to find unusual patterns and works better than traditional methods that rely on known attack signatures.

[5] **Review of IoT Applications in Smart Cities** This review summarizes how IoT is being used in smart cities around the world, including areas like transportation, waste management, energy, and healthcare. It also mentions the tools that make this possible and points out areas where more research is needed, especially around sustainability and security.

[6] **Security and Privacy Risks in Smart Cities and Industries** This study looks at the security and privacy problems in IoT-based smart cities and industries. It covers possible weaknesses, types of cyber threats, and challenges in managing security. It also suggests solutions like data encryption, safer communication tools, and ways to protect privacy.

[7] **Deep Learning-Based IDS for IoT Networks** This paper introduces a deep learning system for detecting intrusions in IoT networks using models like CNN and LSTM. The results show that this system performs better and adapts more easily to new attacks than traditional intrusion detection systems.

[8] **SDN-Based Framework for DDoS Prevention in Smart Cities** This research presents a framework that uses Software-Defined Networking along with machine learning to find and stop DDoS attacks quickly. The system helps the network handle more traffic, reduces false alarms, and improves the performance of the network.

[9] **Optimization and Deep Learning for IoT Smart Cities** This study mixes a billiards- inspired optimization method with deep learning to find unusual activity in IoT networks. It helps with using resources better and makes the network more secure, helping smart cities run more efficiently and reliably.

[10] **Snake Optimizer with Ensemble Learning for DDoS Detection** This paper introduces a new way to detect DDoS attacks by combining the Snake Optimizer with Ensemble Learning. The optimizer helps the model work better by adjusting its settings, leading to high accuracy, precision, and recall in IoT environments.

3.1 IoT-Based Waste Monitoring Systems

Many studies have looked into using IoT technology to track how full garbage bins are. Usually, these systems use sensors like ultrasonic, infrared, or capacitive ones inside the bins. These sensors measure the distance from the top of the bin to the top of the waste, which helps estimate how full the bin is. For example, Sharma et al. (2019) created an IoT- based system that uses ultrasonic sensors and GSM modules to send fill level data to a central server where it can be viewed [1]. Likewise, Patel and Doshi (2020) designed a smart bin system using LoRaWAN for sending data over long distances with low power, which is useful in rural areas for waste management [2]. These systems help waste management teams respond faster and avoid bins overflowing by sending alerts when certain levels are reached. They often come with dashboards, apps, or cloud platforms so city officials can check the status of bins in real time and get reports. However, most of these systems only focus on the current state of the bins and don't take into account how that information can be used to plan waste collection or integrate with logistics operations.

3.2 GPS-Based Fleet Tracking Research

GPS tracking is used a lot in different areas of managing vehicle fleets, like transportation, logistics, and garbage pickup. These systems keep an eye on where vehicles are, how fast they're going, and if they're following the right routes. This helps managers see how well things are running and make better decisions. For example, Kumar and Singh (2020) looked at a system that uses GPS and GSM for tracking city vehicles. It sent real-time location info and kept records of the routes taken [3]. Their work showed how better tracking can help watch over workers in the field more effectively. In garbage collection, GPS helps officials check where the trucks are, make sure they complete their routes, and see how well the service is working. Other studies, like the one by Al-Hamadi et al. (2021), combined GPS with tools that track how drivers behave and use industrial telematics to make fleets work better [4]. Even though these studies show the advantages of tracking vehicles, they don't use data from the bins themselves and can't change

collection routes on the fly based on what's needed right now.

3.3 Limitations of Current Systems

Although a lot of research has been done on waste bin monitoring and GPS-based vehicle tracking, there are still some important issues to address: First, most systems handle waste bin monitoring or vehicle tracking separately. There isn't much work on combining these two areas into one system that uses real-time bin data to plan vehicle routes effectively. Second, even when vehicle tracking is in place, routes are often set up ahead of time or changed by hand, not adjusted automatically based on bin fill levels or collection priorities. Third, many current systems only work in small areas and can't handle large amounts of data or many devices at the same time. This makes it hard to scale up. Fourth, most systems just collect data without offering deeper insights. They don't use advanced tools like predicting when bins will be full, spreading out work evenly, or planning for the future. Because there are no fully integrated smart systems that connect bin data with vehicle tracking, it's hard to make real-time decisions and use resources efficiently. These problems show the need for a complete, IoT-based approach to waste management that covers both monitoring and smart decision-making.

4. Design Methodology

A. Java

Java is a class based general-purpose, object-oriented programming language . It is a high- level, strongly typed language with garbage collection that incorporates concepts from several languages including C and C++, but it is not entirely the same. For example, Java does not allow writing unsafe code that might cause vulnerabilities and unexpected behavior. The main building blocks of a Java application are classes, interfaces and packages.

B. Arduino Controller

The Arduino controller is a microcontroller board that serves as the brain of the Smart Waste Collection Vehicle Tracker & Garbage Bin Level Tracker. It reads data from various sensors, such as ultrasonic sensors for garbage bin fill levels, GPS modules for vehicle location, and accelerometers for vehicle movement. The Arduino board then processes this data and makes decisions based on predefined algorithms, such as sending alerts when bins are full or optimizing routes for efficient waste collection. The Arduino controller is also responsible for controlling actuators, such as alarms and lights, to alert drivers and operators of important events. With its built-in Wi-Fi or cellular connectivity, the Arduino board can transmit data to the cloud or a central server for real-time monitoring and analytics. Its compact size, ease of programming, and versatility make the Arduino controller an ideal choice for this IoT application, enabling efficient and intelligent waste management.

C. GPS

A GPS (Global Positioning System) module is a critical component of the Smart Waste Collection Vehicle Tracker, providing accurate location data for waste collection vehicles. The GPS module receives signals from a network of satellites orbiting the Earth, calculating the vehicle's precise location, speed, and direction. This information is then transmitted to the Arduino controller, which uses it to optimize routes, track vehicle movement, and ensure efficient waste collection. The GPS module enables real-time tracking of waste collection vehicles, allowing operators to monitor their location, progress, and performance. This data can be used to improve route planning, reduce fuel consumption, and enhance overall operational efficiency. Additionally, GPS data can be integrated with other sensors and systems, such as garbage bin fill level sensors, to create a comprehensive and intelligent waste management solution. By leveraging GPS technology, waste management agencies can streamline their operations, reduce costs, and improve services to citizens.

D. Ultrasonic Sensor

An ultrasonic sensor is a non-invasive, accurate, and reliable sensor used to measure the fill level of garbage bins in the Smart Waste Collection System. The sensor emits high-frequency sound waves, which bounce off the waste surface and return to the sensor, calculating the distance and converting it into a fill level percentage. This data is then transmitted to the Arduino controller, which triggers alerts and notifications when bins reach a predetermined fill level, ensuring timely collection and preventing overflow. The ultrasonic sensor is ideal for waste level detection due to its durability, low maintenance, and resistance to environmental factors like dust, moisture, and temperature changes. Its accuracy and reliability enable waste management agencies to optimize collection routes, reduce waste disposal costs, and improve community satisfaction. By integrating ultrasonic sensors with GPS and other technologies, the Smart Waste Collection System creates a comprehensive solution for efficient, effective, and sustainable waste management.

E. Button

The button is installed on the garbage bin or waste collection vehicle, allowing users to manually trigger a notification or alert when the bin is full or requires attention. This button can be pressed by waste collection personnel or citizens, sending a signal to the Arduino controller, which then transmits the alert to the central server or operators. The button provides a redundant system for reporting waste bin status, ensuring that waste collection agencies receive timely notifications even if the ultrasonic sensor or other automated systems fail. The button can also be used to report issues like bin damage, vandalism, or other maintenance needs, enhancing the overall efficiency and effectiveness of the Smart Waste Collection System.

F. LED

An LED (Light Emitting Diode) is a visual indicator used in the Smart Waste Collection System to provide real-time feedback and notifications. The LED can be installed on the garbage bin or waste collection vehicle, providing a clear visual signal to waste collection personnel, citizens, or operators. This visual indicator enables quick identification of bins requiring attention, streamlining waste collection operations and reducing overflow incidents.

5: Module Description

The Smart Waste Collection Vehicle Tracker and Garbage Bin Level Tracker system is designed with specific functionalities for three primary user types: Admin, Municipal Corporation representatives, and general Users. Each user type has tailored access to features that enable streamlined waste management and effective communication.

- 1. Admins Module:** core functionalities include the ability to securely login to the system, add accounts for Municipal Corporations, and monitor system activity through viewing and managing system logs. Admins also have full access to all data within the system, allowing them to oversee vehicle information, bin details, and user complaints to ensure proper system functioning and data integrity.
- 2. Municipal Corporation Module:** on the other hand, interact more directly with the vehicle and bin data. After logging in, they can add new vehicles by inputting relevant details such as type and capacity, view or delete vehicle records, and track each vehicle's daily and current location in realtime. They can also add new dustbins into the system, view or delete existing bins, and access a comprehensive list of all bins in their area. To facilitate waste management, they have access to a filter that organizes bins based on their fill levels (Full, Half, Empty), helping them prioritize collection routes. Additionally, Municipal Corporation representatives can view and respond to user complaints, addressing issues in waste collection services promptly.
- 3. Users Module:** Users have functionalities centered on reporting and tracking issues related to waste collection.

They can register and log in to the system to submit complaints about overflowing bins, missed collections, or other relevant issues. Users can view their submitted complaints, delete them if they are resolved, and monitor the status of each complaint, allowing for better transparency and accountability within the waste management process.

6. System Implementation

1. The Admins Module provides core functionalities that empower system administrators to securely log in, manage Municipal Corporation accounts, and monitor system activities. Admins can view and manage system logs, enabling effective oversight and troubleshooting. With full access to all system data, admins can oversee vehicle information, bin details, and user complaints, ensuring data integrity and smooth system functioning.
2. The Municipal Corporation Module allows representatives to directly manage vehicle and bin data within their jurisdiction. After logging in, Municipal Corporation officials can add, view, and delete vehicles, inputting details such as vehicle type and capacity, and track the daily and realtime locations of each vehicle. The module also supports the addition, viewing, and deletion of dustbins, with the ability to filter bins by their fill levels (Full, Half, Empty), facilitating efficient waste collection and route prioritization. Additionally, Municipal Corporation representatives can access and respond to user complaints, enhancing the quality of waste management services.
3. The Users Module is designed to facilitate user engagement in the waste management process through complaint reporting and tracking. Users can register and log in to submit complaints about issues like overflowing bins or missed collections. They have the option to view and delete their complaints if resolved and can track the status of each complaint, fostering transparency and accountability within the waste management system.

7. System Architecture



Fig: System Architecture

The proposed system for Smart Waste Collection Vehicle Tracker C Garbage Bin Level Tracker consists of garbage bin level trackers with ultrasonic sensors, Arduino controllers, LED indicators, and buttons, which send alerts to a central server when bins are full, and waste collection vehicle trackers with GPS modules, Arduino controllers, and Wi-Fi/Cellular modules, which transmit location data to the central server. The central server uses a data analytics platform to process data, store historical information, and provide insights on waste collection operations, while a web/mobile

application enables operators to monitor bin status, vehicle location, and receive alerts. This IoT-based system optimizes waste collection routes, reduces fuel consumption and emissions, improves bin emptying efficiency, and enhances citizen engagement and satisfaction, ultimately leading to a more efficient and sustainable waste management ecosystem. Ultrasonic sensor measures fill level and sends data to Arduino controller. Arduino controller processes data and sends alerts to central server when bin is full. LED indicator shows bin status (green/yellow/red). Button allows manual override/notification. GPS module tracks vehicle location and sends data to Arduino controller. Arduino controller processes data and sends updates to central server. Data analytics platform processes data and provides insights on waste collection operations. Database stores historical data and bin information. Web application allows operators to monitor bin status, vehicle location, and receive alerts

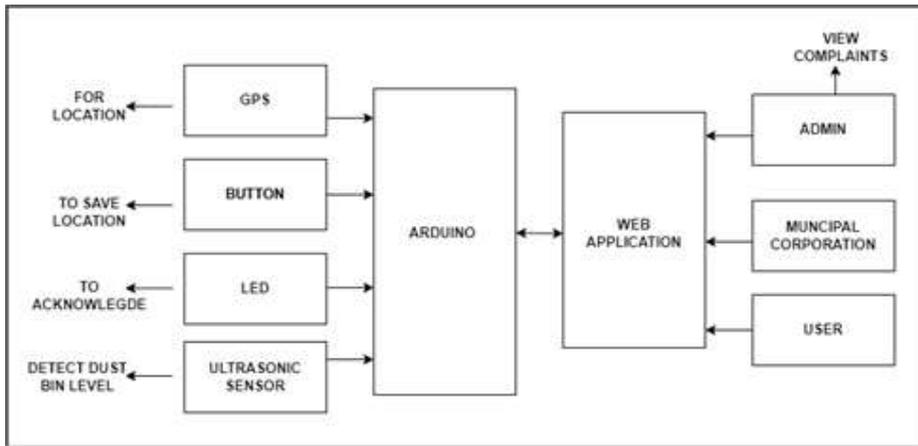


Fig:Block Diagram

8. Proposed System

The Smart Waste Collection Vehicle Tracker and Garbage Bin Level Monitoring System is made to offer a complete, smart, and easy-to-grow waste management solution. It uses IoT to check the levels in garbage bins and GPS to track waste collection vehicles, helping to make waste collection more efficient, cut down on costs, and support better environmental protection.

8.1 Overall System Architecture

A. **Integrated System Overview** The system combines two main parts: Garbage Bin Level Monitoring Module Waste Collection Vehicle Tracking Module These parts talk to a central cloud server that saves, processes, and shows data. The system is built using three

layers: Device Layer – Includes sensors, GPS devices, and small computer chips Communication Layer – Uses networks like GSM, LoRa, or NB-IoT to send and receive data Cloud & Application Layer – Includes the server, storage, analysis tools, and a dashboard This setup allows the bin data to affect how the waste trucks are planned, so the trucks collect waste only when needed, not just on a fixed schedule.

B. **Cloud-Based Monitoring** The cloud server is the main control center of the system. What the cloud platform does: Gathers real-time data from bins and vehicles Stores past data in a database Helps plan the best routes for trucks Sends warnings and updates Shows a live dashboard Features of the dashboard: Map showing where the trucks are Color codes for bin status (Green – Empty, Yellow – Half Full, Red – Full) Reports on how much waste is collected Analysis of how well the system is working Cloud-based monitoring helps make the waste collection system more open, easier to grow, and better controlled.

C. **Communication Flow** The system allows real-time two-way communication between parts. Here’s how the data moves: An ultrasonic sensor measures how full a bin is. A microcontroller processes this data. The data is sent to the cloud server through GSM, LoRa, or another network. GPS sends the truck’s location to the cloud. The cloud server checks which bins need attention and where the trucks are. It then sends the best route to the driver (optional via a mobile app). Protocols like MQTT or HTTP help send the data quickly and efficiently.

8.2 Garbage Bin Level Tracker :- The Garbage Bin Level Tracker keeps an eye on how full individual bins are.

A. How the Ultrasonic Sensor Works

The sensor is placed at the top of the bin inside.

Steps of how it works: The sensor sends out high-frequency sound waves. These waves hit the surface of the waste. They bounce back to the sensor. The time it takes for the echo to return is measured.

Distance is calculated using:

Distance = (Speed of Sound × Time) / 2 The fill level is calculated as:

Fill Level (%) = ((Bin Height – Measured Distance) / Bin Height) × 100

This gives an accurate, contact-free way to check how much waste is in the bin.

B. Microcontroller Processing A microcontroller (like ESP32 or Arduino) does the following: Controls the sensor Calculates the fill level as a percentage Compares it to a set limit Packages the data Sends it to the communication part This ensures the data is processed quickly and uses little power.

C. Alerts Based on Thresholds A set limit (like 80%) is programmed into the system. When the bin is at or above this level: An alert is created The cloud dashboard gets the alert The bin is marked as a high-priority task This stops bins from overflowing and ensures waste is collected on time.

D. Sending Data to the Server The processed data is sent to the cloud server using: GSM module (used in cities) LoRa module (good for long distance and low power) Data is sent either regularly or when the bin reaches the threshold. The dashboard updates in real time.

8.3 Waste Collection Vehicle Tracker

The Vehicle Tracking Module keeps track of the garbage trucks in real time.

A. GPS Tracking System Each truck has a GPS device (like NEO-6M).How it works: The GPS receives signals from satellites. It calculates the latitude and longitude. Sends the coordinates to the microcontroller. Data is sent to the cloud server. This allows precise tracking of where the trucks are.

B. Real-Time Vehicle Monitoring The cloud dashboard shows: Where the truck currently is on the map Where it has been before How fast it's going If it's following the right route This helps authorities watch the trucks and stop them from going off course.

C. Route Optimization The cloud server looks at: How full the bins are Where the trucks are Traffic conditions (if included) The system creates the best routes to: Make the trip as short as possible Use less fuel Make waste collection more efficient This dynamic way of planning routes helps collect waste based on real need.

D. Data Logging All the data from the system is stored in a database, including: How full the bins were over time Where the trucks went When waste was collected What alerts were sent This historical data helps evaluate how well the system works, predict future needs, and plan for the future.

9. Future Scope:

The Future Scope Of Smart Waste Collection Vehicle Tracker C Garbage Bin Level Tracker Is Vast And Exciting. In The Coming Years, The Technology Is Expected To Continue To Evolve And Improve, With Advancements In Areas Such As Artificial Intelligence, Machine Learning, And The Internet Of Things (Iot). This Will Enable More Accurate And Real-Time Tracking, Predictive Maintenance, And Optimized Routing. Additionally, The Integration Of Other Technologies, Such As Sensors And Data Analytics, Will Provide Even More Insights Into Waste Collection Operations, Enabling Waste Management Companies To Make Data-Driven Decisions. Furthermore, The System Will Also Enable Real-Time Monitoring And Control Of Waste Collection Operations, Allowing For Swift Response To Issues And Improved Customer Satisfaction. The Future Scope Of This Technology Also Includes The Potential For Expansion Into Other Areas, Such As Smart Cities, Smart Transportation, And Environmental Sustainability.

10. Conclusion:

In conclusion, the smart waste collection vehicle tracker C garbage bin level tracker is a cutting-edge technology that has revolutionized the waste collection industry by providing real-time visibility, accuracy, and efficiency. By tracking waste collection vehicles and monitoring garbage bin levels, waste management companies can optimize their operations, reduce costs, and improve customer satisfaction. The technology also offers numerous benefits, including reduced fuel consumption, lower emissions, and improved worker safety. As the technology continues to evolve, it is expected to play an even more critical role in shaping the future of waste management.

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