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SWMS : IoT-Based Smart Waste Monitoring System

By

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Bachelor of Science in Computer Science (2020-2024)

The candidate confirms that the work submitted is their own and appropriate credit has been given where reference has been made to the work of others.

DECLARATION

We hereby declare that this software, neither whole nor as a part has been copied out from any source. It is further declared that we have developed this software documentation and accompanied report entirely on the basis of our personal efforts. If any part of this project is proved to be copied out from any source or found to be reproduction of some other. We will stand by the consequences. No Portion of the work presented has been submitted of any application for any other degree or qualification of this or any other university or institute of learning.

Muhammad Shoaib Qureshi	Muhammad Umer Kashmiri	Muhammad Fahad Khan
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CERTIFICATE OF APPROVAL

It is to certify that the final year project of BS (CS) "IoT-Based Smart Waste Monitoring System" was developed by "Muhammad Shoaib Qureshi ,   20-ARID-3901", "Muhammad Umer Kashmiri ,   20-ARID-3912" and "Muhammad Fahad Khan ,   20-ARID-3875" under the supervision of "Mr Nouman ul Hassan" and that in their opinion; it is fully adequate, in scope and quality for the degree of Bachelors of Science in Computer Science.

Supervisor

Executive Summary

The Smart waste monitoring system aims to revolutionize the traditional waste collection methods by introducing an efficient, technology-driven solution. This system addresses the shortcomings of existing waste monitoring systems, offering real-time monitoring capabilities. This project aligns with the courses studied during the degree program, integrating principles from electronics, web development, database management, and information technology. The emphasis on these diverse courses reflects the interdisciplinary nature of the project.

The project's foundation lies in the Internet of Things (IoT) and Smart Cities research, focusing on real-time waste monitoring. Drawing from literature reviews on waste monitoring systems, the analysis highlights limitations in current systems, such as irregular collections, inefficient sensor integration, and a lack of automated notification systems. This project seeks to overcome these challenges and contribute to the evolving field of smart waste management.

The chosen methodology for this project combines structural and object-oriented approaches, aligning with the software development life cycle (SDLC). This choice ensures a systematic and comprehensive development process. The rationale behind this selection is rooted in the need for a robust and scalable solution that aligns with industry best practices.

In the context of literature review analysis, the project aims to surpass the limitations identified in existing waste monitoring systems. Leveraging IoT and smart technologies, the proposed system strives for real-time monitoring, efficient waste collection, and automated notification systems to streamline waste management processes.

The methodology and SDLC model chosen for the project are driven by the need for a structured and iterative development process. By combining structural and object-oriented approaches, the project aims to achieve a balance between efficiency, scalability, and maintainability throughout the software development life cycle.

The use cases outlined in the requirement analysis chapter provide a detailed insight into the functionality of the system. Key use cases, such as alert generation, web interface, data visualization, user authentication, and security measures, contribute to the comprehensive

coverage of the system's features. These use cases serve as a foundation for the subsequent design and implementation phases.

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Acknowledgement

All praise is to Almighty Allah who bestowed upon us a minute portion of His boundless knowledge by virtue of which we were able to accomplish this challenging task.

We are greatly indebted to our project supervisor “Mr Nouman ul Hassan” for personal supervision, advice, valuable guidance and completion of this project. We are deeply indebted to him for encouragement and continual help during this work.

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Muhammad Shoaib Qureshi	Muhammad Umer Kashmiri	Muhammad Fahad Khan
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Abbreviations

SRS	Software Requirement Specification
PC	Personal Computer

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Chapter 1: Introduction

This chapter provides the overview of the project. The first paragraph of every chapter should provide the chapter summary.

1.1. Brief

The project titled "IoT-Based Smart Waste Monitoring System" aims to develop an innovative waste management solution utilizing real-time data analysis through laser and weight sensors. The system's key outcome is the creation of an efficient waste monitoring system that optimizes collection routes, reduces operational costs, and promotes sustainable waste management. The project employs a systematic methodology, integrating laser and weight sensors to collect real-time data from waste bins. Custom algorithms are then used to process and analyze this data, and the results are presented through a user-friendly web interface developed with web languages. The tools utilized include VS Code for coding, documentation tools for reporting, and various web languages for interface development. The project's holistic approach combines hardware and software components to enhance waste management processes and contribute to a more eco-friendly system.

1.2. Relevance to Course Modules

This project seamlessly integrates knowledge acquired across various degree courses, including electronics, web development, database introduction, and information on computer technology. Leveraging insights from electronics courses, we implemented laser and weight sensors at the hardware level for the IoT-based Smart Waste Monitoring System. Web development courses equipped us with the skills to create an intuitive user interface using web languages, ensuring effective data presentation. The database introduction course played a pivotal role in structuring and managing the data generated by the system. Insights from courses on computer technology provided a broader context, enabling the development of a holistic and integrated IoT solution. In essence, our project represents a synthesis of skills and concepts from these diverse courses, showcasing a practical application of our academic learnings.

1.3. Project Background

The project is driven by the imperative for advanced waste management solutions in response to the limitations of conventional systems. Focused on the Internet of Things (IoT), the IoT-Based Smart Waste Monitoring System utilizes laser and weight sensors embedded in waste bins to continuously monitor fill levels. This real-time data undergoes analysis through tailored algorithms, addressing challenges in waste collection route optimization and adaptability to changing waste volumes. The project's foundational concept lies in leveraging IoT technologies to revolutionize waste management practices, providing timely and accurate insights. Through this system, the aim is to achieve optimized collection routes, cost reduction, and a more sustainable waste management process. This project background underscores the critical need for innovative approaches in waste management and highlights the potential of IoT applications in addressing these challenges.

1.4. Literature Review

The existing waste Monitoring systems have limitations in real-time monitoring.
IoT in Smart Cities : [B. N. Silva, M. Khan, and K. Han] - Lacks real-time monitoring, resulting in irregular collections.
“ Communication in Internet of Things”, : Monika Kashyap, Vidushi Sharma, Neeti Guptam Ajmal Khan, et.al, “IoT based smart waste bin to track dustbin and public complaint management system.” 8th IEEE International conference Communication System and Network Technology -2018, DOI10.1109/CSNT.2018.8820272.

1.5. Analysis from Literature Review (in the context of your project)

Our project, the IoT-based Smart Waste Monitoring System, directly responds to the real-time monitoring gaps identified in the literature. Unlike systems noted in the review, our solution ensures continuous monitoring through laser and weight sensors, overcoming issues of irregular waste collections. Additionally, insights from the "Communication in Internet of Things" study guide our project in implementing effective communication systems, introducing automated alerts for streamlined waste collection. This analysis highlights our project's commitment to overcoming existing limitations in waste management systems.

1.6. Methodology and Software Lifecycle for This Project

The project employs a hybrid methodology, combining aspects of waterfall and Agile approaches. It begins with a thorough analysis and design phase akin to the waterfall model, followed by an Agile implementation, testing, and deployment process. The Agile Software Development Life Cycle (SDLC) model is chosen for its adaptability to changing project requirements and emphasis on iterative development. This approach ensures a balanced integration of hardware and software components in the creation of the IoT-based Smart Waste Monitoring System, promoting flexibility while maintaining structured planning throughout the project lifecycle.

1.6.1. Rationale behind Selected Methodology

The choice of a hybrid methodology, combining structural and object-oriented principles, stems from the specific needs of the project. This approach allows for a systematic initial phase similar to the waterfall model, addressing the intricacies of hardware and software integration. Transitioning to an object-oriented methodology within an Agile framework facilitates iterative development and accommodates evolving project requirements. This tailored blend ensures a structured yet adaptable approach, aligning with the dynamic nature of the IoT-based Smart Waste Monitoring System.

1.6.1.1. Rationale behind Selected Methodology

The rationale for opting for a *hybrid methodology* stems from the need for a balanced and adaptive approach. By blending structural and object-oriented principles, we aim to combine the systematic planning inherent in the waterfall model with the flexibility and responsiveness of an object-oriented methodology within an Agile framework. This tailored approach ensures a harmonious and well-suited methodology for developing the IoT-based Smart Waste Monitoring System, allowing us to navigate through both structured planning and evolving project dynamics seamlessly.

Chapter 2: Problem Definition

This chapter discusses the precise problem to be solved. It should extend to include the outcome.

2.1. Problem Statement

The problem at hand pertains to the inefficient waste Monitoring practices prevalent in the areas, which result in sub-optimal resource allocation and increased operational costs. Traditional waste collection systems often lack the capability to monitor the fill levels of dustbins in real-time. This leads to challenges in maintaining cleanliness and hygiene in public spaces. The absence of automated notifications for waste collection authorities exacerbates the problem, causing delays in waste removal and a negative impact on surrounding environments.

2.2. Deliverables and Development Requirements

The Deliverables and development requirements are:

Deliverables Requirements

IoT-Based Smart Waste Monitoring System Prototype:
A functional prototype demonstrating real-time monitoring capabilities through integrated sensors.User-friendly interface for visualizing waste levels and system alerts.

Web Application:
An intuitive web application for waste collection authorities to access real-time data and receive automated notifications.Efficient data visualization tools for route optimization and resource allocation.

Documentation:
Comprehensive technical documentation detailing system architecture, design, and implementation.User manuals for both end-users and waste collection authorities.

Training Materials:
Training materials and sessions for end-users and administrators to ensure effective utilization of the system.

Development Requirements:

Hardware Components:
IoT devices with integrated laser and weight sensors for accurate data collection. Communication modules for seamless data transmission.Robust and durable dustbin attachments to house the sensors.

Software Components:

Programming languages (Html,CSS,Bootstrape,JS,reactJS ,Laravel) for system development.Integration of database systems for data storage and retrieval.Development tools such as VS Code for coding efficiency.

Cloud Services:
Utilization of cloud services for scalable data storage and processing.Implementation of secure communication protocols for data transmission.

Security Measures:
Integration of security protocols to safeguard user data and system integrity.
Regular system audits and updates to address potential vulnerabilities.
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Chapter 3: Requirement Analysis

Software Requirements Specification (SRS) report should be included in this chapter.

3.1. Use Cases

Use Case ID:	UC.3.1
Use Case Name:	Sensor integration
Actors:	Sensor(Primary)
Description:	This use case involves the integration of sensor devices, including laser and weight sensors, into waste bins for real-time data collection. The system interacts with the sensor devices to gather information on the fill levels of the waste bins.
Trigger:	The system receives a signal from the sensors indicating a change in waste bin levels.
Preconditions:	Sensor devices are installed and operational. The system has access to the necessary communication channels for interacting with sensor devices.
Postconditions:	Real-time data on waste bin fill levels is successfully integrated into the system. The system is ready to process and analyze the collected data for further actions.
Normal Flow:	1. The system initiates communication with sensor devices. 2. Sensor devices respond by providing real-time data on the fill levels of waste bins. 3. The system validates and processes the received data. 4. Processed data is stored in the system database for future analysis. 5. The system updates the user interface with the latest waste bin fill level information. 6.
Alternative Flows: [Alternative Flow 1 – Not in Network]	Alternative Flow 1 – Sensor Communication Failure In step 2 of the normal flow, if sensor devices fail to respond: The system generates an alert for a communication failure. The use case resumes normal flow when communication is restored.
Exceptions:	**Security Breach (Exception 1):** 1. If a security breach is detected. 2. The system initiates security protocols. 3. Relevant authorities are notified.

	4. Use case resumes at step 5 of the normal flow.
Includes:	[Authentication and Authorization Module
Special Requirements:	The system must support secure data transmission and storage.
Assumptions:	The sensors are regularly calibrated for accuracy.
Notes and Issues:	What is the maximum distance between a sensor module and the main monitoring system?

3.2. Use Case

Use Case ID:	UC.3.2
Use Case Name:	Real Time Data Processing
Actors:	Sensor (Primary)
Description:	This use case involves the continuous monitoring of waste bin fill levels in real-time by the system using integrated sensors.
Trigger:	The system receives a signal from the sensors indicating a change in waste bin levels.
Preconditions:	The sensors are properly installed and connected to the system.
Postconditions:	The system updates the database with the latest waste bin fill level data.
Normal Flow:	7. The sensors detect a change in waste levels. 8. The system captures real-time data from the sensors. 9. The data is processed to determine the current fill level. 10. If the fill level exceeds a predefined threshold, an alert is generated.
Alternative Flows: [Alternative Flow 1 – Not in Network]	*Inconsistent Sensor Data (Alternative Flow 1):** 1. If the sensor data is inconsistent. 2. An error message is logged. 3. Use case resumes at step 5 of the normal flow. - **Alert Generation Failure (Alternative Flow 2):** 1. If the system fails to generate an alert. 2. An error notification is sent. 3. Use case resumes at step 5 of the normal flow.
Exceptions:	Invalid Data from Sensors 1.The system generates an alert for data validation failure. 2. The invalid data is logged for further analysis. 3. The use case resumes normal flow with a reattempt to obtain valid data.
Includes:	Null
Special Requirements:	The system must ensure secure communication with sensor devices to prevent unauthorized access.
Assumptions:	It is assumed that the sensor devices are correctly installed and

	configured. Communication channels between the system and sensor devices are assumed to be operational.
Notes and Issues:	What is the maximum distance between a sensor module and the main monitoring system?

3.3. Use Case

Use Case ID:	UC.3.3
Use Case Name:	Alert Generation
Actors:	Primary Actor: Sensor Secondary Actor: User
Description:	This use case involves the generation of alerts by the system based on the analyzed data. The alerts notify the Waste Management Authority about critical conditions or events, ensuring timely and effective response.
Trigger:	The trigger for this use case is the completion of data analysis, indicating the identification of critical waste management conditions.
Preconditions:	Data analysis is successfully completed. The system has access to contact information for the Waste Management Authority.
Postconditions:	Alerts are successfully generated by the system. The Waste Management Authority receives alerts.
Normal Flow:	1. The system identifies critical conditions based on data analysis. 2.The system generates alerts specifying the nature of the critical conditions. 3.Alerts are sent to the Waste Management Authority through the designated communication channels.
Alternative Flows: [Alternative Flow 1 – Not in Network]	None
Exceptions:	Failure to Generate Alerts In case of a system failure to generate alerts: The system logs the failure. The Waste Management Authority is notified about the failure. The system attempts to resend alerts periodically until successful. 3. The use case resumes normal flow with a reattempt to obtain valid data.

Includes:	Null
Special Requirements:	The system should be capable of sending alerts through multiple communication channels. The alert content should clearly specify the critical conditions identified.
Assumptions:	The contact information for the Waste Management Authority is accurate and up-to-date.
Notes and Issues:	The system should provide a log of all alerts sent, including success and failure records.

3.4. Use Case

Use Case ID:	UC.3.4
Use Case Name:	Web Interface
Actors:	Primary Actor: Sensor Secondary Actor: User
Description:	This use case involves the interaction between the user and the system through the web interface. Users can access the web interface to monitor waste levels, view reports, and perform administrative tasks.
Trigger:	The trigger for this use case is the user accessing the web interface.
Preconditions:	The user interacts with the web interface successfully. Any data entered or actions performed by the user are processed by the system.
Postconditions:	The user interacts with the web interface successfully. Any data entered or actions performed by the user are processed by the system.
Normal Flow:	The user accesses the web interface through a web browser. The system prompts the user to log in. The user enters valid login credentials. The system verifies the credentials and grants access to the web interface. The user navigates through the web interface to: View real-time waste levels. Access historical waste data and reports. Configure system settings (if authorized). Generate specific alerts (if authorized). The user logs out or closes the web browser when done.
Alternative Flows:	Alternative Flow 1 – Invalid Login Credentials If the user enters invalid login credentials:

[Alternative Flow 1 – Not in Network]	The system prompts the user to enter valid credentials. Steps 3-4 are repeated.
Exceptions:	Exception 1 – Web Interface Unavailable If the web interface is unavailable: The system displays an error message. The user is advised to try again later.
Includes:	Null
Special Requirements:	The web interface should be responsive and user-friendly. Access to certain features may be restricted based on user roles.
Assumptions:	The user has a basic understanding of using web interfaces. The system is connected to the internet for web interface access.
Notes and Issues:	Regular maintenance schedules should be communicated to users to avoid disruption of web interface services.

3.5. Use Case

Use Case ID:	UC.3.5
Use Case Name:	Data visualization
Actors:	Primary Actor: Sensor Secondary Actor: User
Description:	This use case involves the visualization of waste management data for users. Users can interact with visual representations of data to gain insights into waste levels, trends, and other relevant information.
Trigger:	The trigger for this use case is the user's request to visualize waste management data.
Preconditions:	The user has successfully logged into the system. Sufficient waste data is available for visualization.
Postconditions:	The user interacts with the data visualization successfully. The system processes user requests for data visualization.
Normal Flow:	The user navigates to the data visualization section of the system. The system presents options for data visualization, such The user selects the type of visualization they want to see. The system retrieves relevant data and generates the selected visualization. The user interacts with the visualization to: Zoom in/out. Filter data based on specific parameters. View details by hovering over data points.

	Customize the appearance of the visualization. The user can switch between different types of visualizations for a comprehensive view. The user exits the data visualization section when done.
Alternative Flows: [Alternative Flow 1 – Not in Network]	Insufficient Data for Visualization If there is insufficient data for the selected visualization: The system notifies the user about the lack of data. The user may choose an alternative visualization or adjust the parameters.
Exceptions:	Data Visualization Error If there is an error in generating the visualization: The system displays an error message. The user may attempt to generate the visualization again.
Includes:	Null
Special Requirements:	The data visualization feature should be responsive and provide real-time updates. Users should have the option to save or export visualizations for reporting purposes.
Assumptions:	The user has basic knowledge of interpreting data visualizations. The system has access to a sufficient amount of waste management data.
Notes and Issues:	User feedback on the effectiveness of visualizations should be considered for continuous improvement.

3.6. Use Case

Use Case ID:	UC.3.6
Use Case Name:	User Authentication
Actors:	Primary Actor: Sensor Secondary Actor: User
Description:	This use case involves authenticating users who attempt to access the waste management system. User authentication ensures that only authorized individuals can log in and interact with the system.
Trigger:	The trigger for this use case is a user attempting to log into the waste management system.
Preconditions:	The user has an active account in the waste management system. The user has a valid username and password.
Postconditions:	The user interacts with the data visualization successfully. The system processes user requests for data visualization.
Normal Flow:	The user navigates to the system's login page. The system prompts the user to enter their username and password.

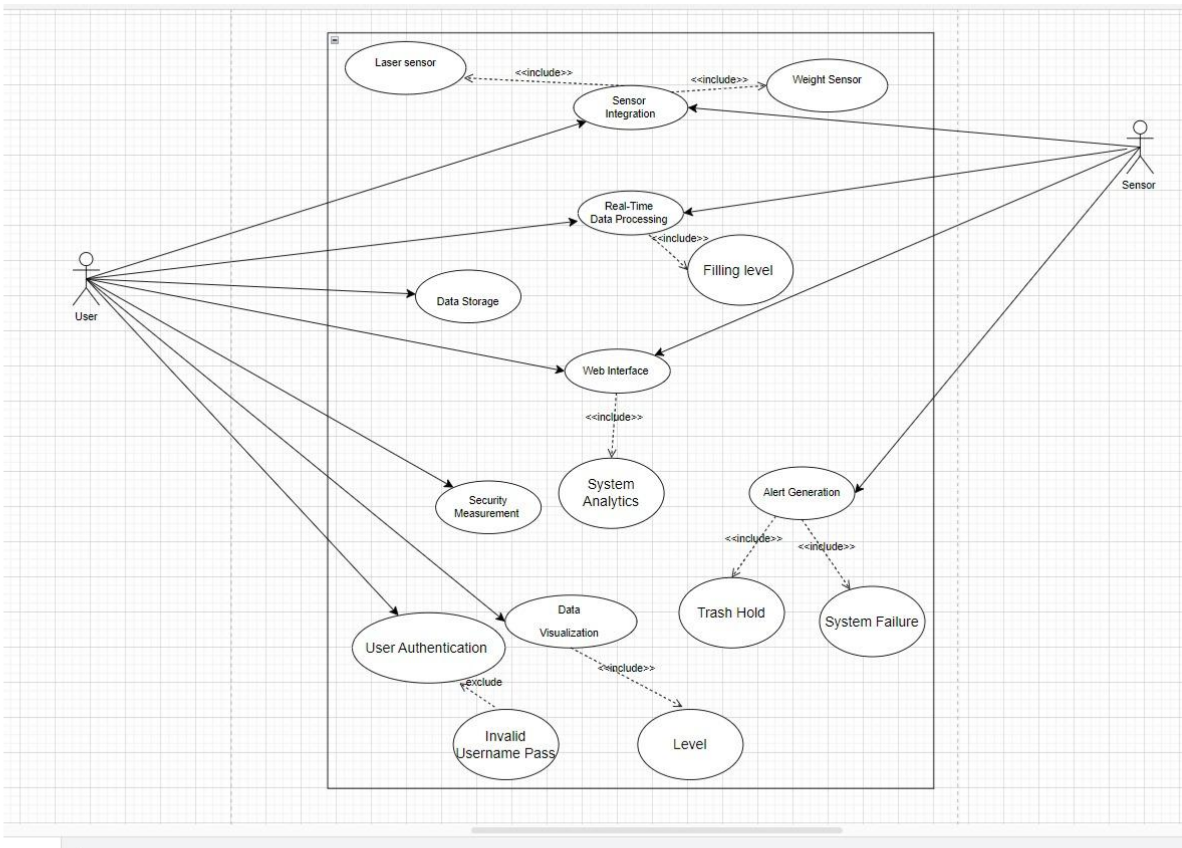
	The user enters their valid credentials. The system verifies the entered credentials against the stored user data. If the credentials are valid, the system grants access to the user. The user is redirected to the system's dashboard or designated landing page.
Alternative Flows: [Alternative Flow 1 – Not in Network]	**Invalid Credentials If the entered credentials are invalid: The system notifies the user of the authentication failure. The user may attempt to re-enter their credentials or use the password recovery option.
Exceptions:	Account Lockout If there are repeated failed login attempts: The system may temporarily lock the user account. The user is informed about the account lockout and advised to contact support.
Includes:	Null
Special Requirements:	Passwords must meet specified security criteria (e.g., minimum length, combination of characters). The system should include features like password recovery and account unlocking..
Assumptions:	Users are responsible for keeping their login credentials confidential. The system securely stores and encrypts user passwords.
Notes and Issues:	Regularly review and update security measures to protect against unauthorized access.

3.7. Use Case

Use Case ID:	UC.3.7
Use Case Name:	Security Measure
Actors:	Primary Actor: Sensor Secondary Actor: User
Description:	This use case involves implementing and maintaining security measures within the waste management system to safeguard against unauthorized access, data breaches, and other security threats.
Trigger:	The trigger for this use case is the need to enhance or update the security measures within the waste management system.
Preconditions:	The system is operational. The system administrator has the necessary privileges to manage security settings.
Postconditions:	Security measures are successfully implemented or updated. The system administrator reviews and confirms the effectiveness of

	the security measures.
Normal Flow:	The system administrator accesses the security settings within the waste management system. The administrator reviews the existing security measures and identifies areas for improvement. Based on the assessment, the administrator adjusts or enhances security configurations. The system updates its security protocols and measures.
Alternative Flows: [Alternative Flow 1 – Not in Network]	Emergency Security Update In the event of a security vulnerability or emergency, the system administrator may expedite the implementation of critical security updates. The administrator communicates the urgency of the update to relevant stakeholders.
Exceptions:	**Unsuccessful Update If there are issues during the update process: The system may revert to the previous security configuration. The administrator is alerted about the unsuccessful update and takes corrective action.
Includes:	Null
Special Requirements:	Regular security audits and assessments should be conducted to identify potential vulnerabilities. The system should support multi-factor authentication and encryption.
Assumptions:	The system administrator is knowledgeable about current security best practices. Users are notified of any planned downtime or disruptions related to security updates.
Notes and Issues:	Document and communicate changes in security measures to relevant stakeholders. Keep abreast of emerging security threats and update measures accordingly.

Use Case Diagrame



3.8. Functional Requirements

The functional requirements for the IoT-based Smart Waste Monitoring System, considering it is a web-only application, are outlined below:

Sensor Integration:

The system shall integrate laser and weight sensors into waste bins for real-time data collection.
Sensors should accurately measure and transmit data regarding waste levels.

Real-Time Data Processing:

The system shall process data collected from sensors in real time.
Algorithms will be employed to analyze the data and determine current waste bin fill levels.

Alert Generation:

If the fill level of a waste bin exceeds a predefined threshold, the system shall generate an alert.
Alerts may include notifications to waste collection authorities or relevant personnel.

Web Interface:

The system shall have a responsive web interface accessible to waste collection authorities.
The web interface will display real-time data, including fill levels, status alerts, and system analytics.

Data Visualization:

The web interface shall incorporate data visualization tools for presenting waste bin fill levels.
Graphs, charts, and maps may be utilized to enhance the understanding of data patterns.

Historical Data Storage:

The system shall store historical data related to waste bin fill levels.
Archived data will be accessible for trend analysis and long-term planning.

User Authentication and Authorization:

The web interface shall require user authentication for access.
Different levels of authorization will be implemented, allowing varying access levels for different users.

Security Measures:

The system shall implement security protocols to safeguard data integrity and user privacy.
Secure communication channels and encryption mechanisms will be employed.
These functional requirements cater specifically to a web-only application, ensuring efficient real-time monitoring and analysis of waste management processes through the accessible web interface.

3.9. Non-Functional Requirements

Performance:

The system shall respond to user requests within 2 seconds.
It should handle a simultaneous user load of at least 1000 users.

Reliability:

The system shall have a 99.9% uptime.
In the event of a system failure, data recovery should occur within 2 hours.

Scalability:

The system should easily scale to accommodate an increase in the number of waste bins and users.
Scalability tests should be conducted to ensure efficient performance under varying loads.

Security:

All communication between the web interface and the server shall be encrypted using HTTPS.
User data, especially authentication information, shall be securely stored and hashed.
Regular security audits and vulnerability assessments shall be conducted.

Usability:

The web interface shall be intuitive and user-friendly.
A user satisfaction survey shall be conducted biannually to gather feedback for continuous improvement.

Compatibility:

The web interface shall be compatible with major web browsers (Chrome, Firefox, Safari, Edge).
The system shall be platform-agnostic and accessible from both desktop and mobile devices.

Maintainability:

Code shall adhere to coding standards and best practices.
Documentation for code, APIs, and system architecture shall be maintained and regularly updated.

Interoperability:

The system should integrate seamlessly with external APIs for weather data, traffic updates, and other relevant information.
APIs shall follow industry standards to facilitate future integrations.

Data Backup and Recovery:

Regular backups of the database shall be performed daily.
A disaster recovery plan shall be in place, specifying procedures for data restoration in case of a catastrophic event.

Environmental Impact:

The system shall aim to minimize its environmental impact by optimizing waste collection routes for fuel efficiency.
Sustainable practices, such as using electric vehicles, shall be explored for waste collection.

Regulatory Compliance:

The system shall comply with data protection regulations and privacy laws.
It shall adhere to local waste management regulations and standards.

Training and Support:

Training sessions shall be conducted for waste collection personnel on using the system effectively.
A dedicated support team shall be available during business hours for user assistance.