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Summary

This interim report presents the shaping process of the “WasteWise” system – an IoT and AI concept designed to improve the classification, segregation, and monitoring of waste. At the present time, the research and designing stage of the project are in progress; however, the user research results, technical viability of the project, and preliminary concept design and prototyping have already been carried out. AI-based waste classification, active tracking, and error detection features are still under development with a plan to release and optimize in v2/v3. The technologies used for the development of WasteWise includes Python, TensorFlow, PyTorch, OpenCV, Django, React to address landfill overuse and minimize pollution. The project employed the evolutionary prototyping approach that guarantees the successive model update and user input. In this paper, the opportunity to enhance the rate of recycling and minimize pollution attributable to waste is overviewed, and the subsequent stages of the project and the further planned results are described.

Table of Contents

Table of Figures

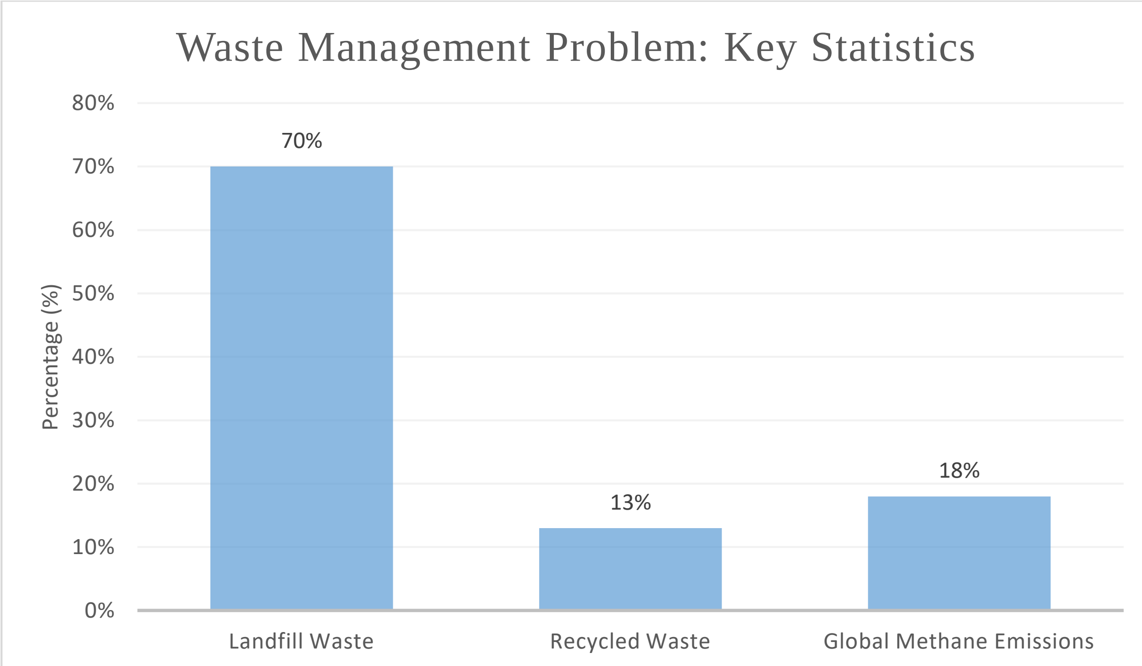
Table of Tables

1. Introduction

Figure 1: The landfill site in Sisdol, in operation since 2005, is already beyond its carrying capacity.

This proposal discusses how Nepal, a developing country situated in the Himalayan region, confronts huge environmental problems related to waste management, which are comparable to those in developed countries or even worse. High population growth, increase in conducive urban areas and inadequate resource in managing waste has led into a rush waste management issue. According to the source, Kathmandu valley produces about 1,200 tons of Municipal Solid Waste daily, out of which 35-40% of it is collected and only 10-15% is treated or recycled *(Post, 2021)*. The rest of it is usually disposed to unsafe landfills or is openly burnt thus posing serious environmental and health hazards. The climatic conditions, the geographical location and the complications arising out of it adds up to these problems; that makes it even more urgent and imperative for having innovative solution to the waste management problems for the sustainable development of Nepal.

1.1. Problem Scenario



The problem that revolves around waste management is even worse, and based on estimates it is expected that landfill waste will increase by 70% by 2050 as is shown in What a Waste 2.0 report from the World Bank *(Bank, 2018)*. This statistic alone speaks volumes as to why there should be viable waste management technologies being implemented. Now, about one point three billion tons of waste are produced yearly and only slightly more than a tenth of this amount undergoes recycling. Most of them are chucked into dumpsites resulting to substantial deterioration of the natural environment and loss of resources.

In addition, the management of such facilities is attributed to 18% of the global methane emissions which is a prevalent greenhouse gas *(Commisions, 2022)*. These and many similar problems point to shifts that dictate the search for effective additional practices to address waste sorting and their environmentally sound management as existing traditional approaches are no longer sufficient to decrease the overall volume of waste with its negative effects.

These issues are further complicated by factors such as relatively low technological advancement in the larger global community, restricted municipal funding, and a conspicuous absence of coherent waste management policies particularly in developing countries including Nepal.

1.2. Project as a Solution

To solve these pressing issues, the WasteWise project introduces an innovative solution: an innovative Internet of Things (IoT) and Artificial Intelligence (AI) integrative smart dustbin intended to self-sort waste items into bio-degradable and non-bio-degradable categories. This intelligent system improves current waste management practices by incorporating intelligent technologies that can help in sorting and supervision that is important to Nepal and other countries struggling with waste management challenges.

1.3. Features of the Solution:

1.3.1. Must Have Features

- **Automated Waste Classification:** The system is capable of classifying biodegradable and non-biodegradable waste, hence, there is very little likelihood of poor segregation due to use of artificial intelligence algorithms.
- **Real-time Monitoring:** The use of an all-encompassing web application allows users to monitor the levels of waste and the status of bins as well as produce instant notifications to ensure that waste is managed professionally.
- **User-Friendly Interface:** The solution offers the facility to manage day-to-day waste and engage the users in various waste recycling activities with an easy and interactive UI.
- **Error Detection Mechanism:** An intelligent error detection system lets the user, correct classify the misclassified waste thereby makes waste segregation easy and efficient.

1.3.2. Could Have Features

- Advanced analytics for waste composition trends.
- Integration with municipal waste collection systems.
- Multi-category classification for more granular sorting (e.g., separating plastics by type).

1.4. Expected Impact

The implementation of WasteWise aims to create concrete, measurable improvements in waste management through targeted interventions:

- **Reduce Environmental Pollution:**
  - Decrease mixed waste in landfills by up to 60% through accurate segregation *(Blair, 2021)*.
  - Reduce soil and groundwater contamination by preventing improper waste disposal.
  - Minimize microplastic leakage into local ecosystems by ensuring proper sorting of plastic waste *(Dolipas, 2020).*
  - Potential reduction of harmful waste-related pollutants by preventing open burning and uncontrolled dumping.
- **Minimize Landfill Waste:**
  - Redirect approximately 40-50% of collected waste to recycling and composting streams *(Government of India, NITI Aayog , 2023)*.
  - Extend the lifespan of existing landfills by reducing waste volume.
  - Decrease in land area required for waste disposal by more efficient waste management.
  - Potential cost savings for municipalities through reduced landfill management expenses (estimated 25-35% reduction).
- **Lower Greenhouse Gas Emissions:**
  - Reduce methane emissions from landfills by up to 30% through improved waste segregation.
  - Decrease carbon footprint by facilitating easier recycling and composting processes.

- Potential annual reduction of 2-3 tons of CO_2 equivalent per deployed smart dustbin
- Support local and national climate change mitigation efforts

1.5. Aim and Objectives

1.5.1. Aim

To design and develop an intelligent waste management system utilizing AI and IoT technologies for efficient classification, segregation, and monitoring of waste, to promote sustainable disposal practices.

1.5.2. Objectives

- **Automated Lid Mechanism Design**
  - Develop a proximity sensor-based lid mechanism that achieves 95% accuracy in detecting user presence and automatically opens within 1-2 seconds of approach.
  - Complete prototype development and initial testing within 3 months.
- **AI-Powered Waste Classification System**
  - Create a machine learning algorithm capable of classifying waste into at least 6 distinct categories (e.g., organic, plastic, paper, metal, glass, e-waste) with 90% classification accuracy.
  - Train the AI model using a dataset of 10,000+ waste item images.
  - Reduce manual waste time by 70% compared to traditional methods.
  - Validate system performance within 6 months of initial development.
- **IoT-Enabled Real-Time Monitoring**
  - Design a web application that provides:
    - Real-time waste bin fill-level tracking with 98% accuracy.
    - Instant notifications when bin reaches 80% capacity.

        - User-friendly dashboard displaying waste generation statistics.
    - Develop the monitoring platform within 4 months.
- **Error Detection and Correction Mechanism**
    - Implement an AI-driven error detection system that:
        - Identifies misclassified waste items with 85% accuracy.
        - Allows user manual override and correction.
- **Comprehensive Waste Analytics**
    - Develop data analytics capabilities that:
        - Track waste generation patterns across different times, days, and user groups.
        - Generate detailed monthly reports on waste composition.
        - Provide predictive insights for waste management optimization.
    - Enable data export in at least two standard formats (CSV, Excel).

2. Pre-Survey Analysis

The pre-survey analysis is kept at the appendix section at the end of this document.

Link to the pre-survey analysis: Pre-Survey Analysis

3. Literature Review

The literature review is kept at the appendix section at the end of this document.

Link to the Literature Review: Literature Review

4. Methodology

4.1.1. Considered Methodologies

1. **Waterfall Methodology**: It is a linear and sequential approach to software development. It has clearly defined stages with minimal overlap.
   - **Advantages:**
     - Provides documentation and a clear structure.
     - Effective for projects with clearly defined needs
   - **Disadvantages:**
     - Not adaptable enough for projects that keep on changing.
     - Changes during developments are challenging to accommodate.
     - Project failure is highly likely if requirements are not recognized at an early stage.

2. **Agile Methodology**: It is an iterative and incremental development approach that emphasizes flexibility, collaboration, and rapid delivery.
   - **Advantages:**
     - Highly flexible in response to shifting needs.
     - Constant improvement and feedback
     - Frequent interaction with stakeholders
   - **Disadvantages:**
     - May not have thorough documentation.
     - Possible scope creep
     - Demands devoted and extremely skilled team members.

3. **Spiral Methodology**: It is a risk-driven approach combining iterative development with systematic aspects that focuses on early identification and mitigation of project risks.
   - **Advantages:**
     - Comprehensive risk analysis
     - Makes incremental releases possible.
     - Support intricate, large-scale projects

- **Disadvantages:**
  - Can be complex and expensive.
  - Requires highly experienced manpower to implement.
  - May lead to extended development cycles.

4. **Evolutionary Prototyping**: It is a dynamic approach focusing on continuous refinement and user feedback and develops and evolves prototype iteratively.
   - **Advantages:**
     - Highly flexible in response to shifting needs.
     - Enables early user participation.
     - Minimizes the possibility of creating misaligned solutions.
   - **Disadvantages:**
     - Can result in ambiguity about the scope.
     - Possible longer development period
     - Strong documentation management is necessary.

4.1.2. Selected Methodology

Evolutionary Prototyping is chosen for the WasteWise project as it has unique characteristics that align well with the project's technological and innovative nature. The phases of the project development are as follows:

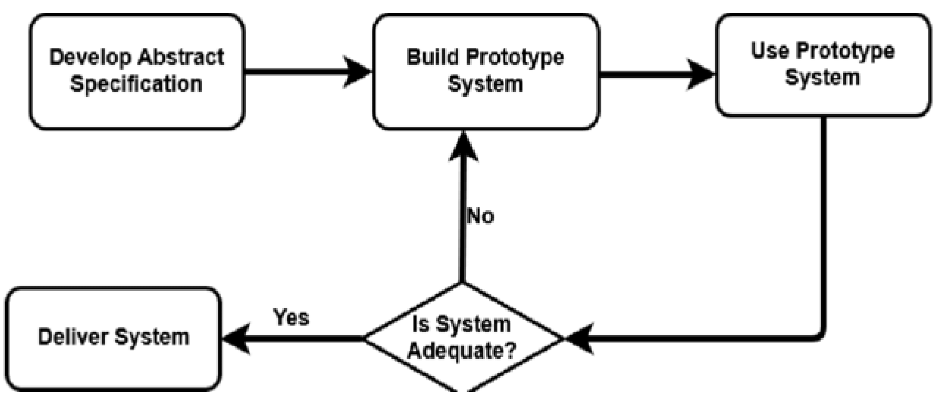


Figure 2: Evolutionary Prototype

1. Research Phase:

- Preliminary requirements gathering and user research.
- Develop initial concept prototype.
- Verify the technical viability and fundamental user requirements.

2. Design Phase:

- Make a draft system architecture.
- Create preliminary UI/UX mock-ups.
- Create the first functional prototype.

3. Development Phase:

- Iterative AI model development
- Incremental integration of software and hardware
- Continuous improvement based on user feedback.
- Progressive features and capabilities growth

4. Testing Phase:

- Ongoing user testing
- Assessment of performance
- Iterative enhancements
- Prototype validation against the initial requirements

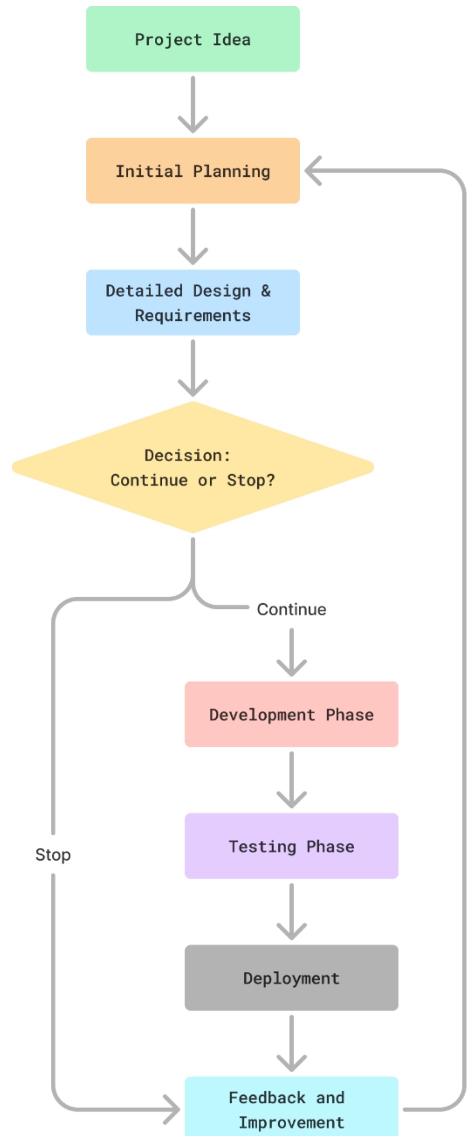


Figure 3: WasteWise SDLC flowchart

5. Resource Requirements

5.1. Hardware Components

- Development workstations with GPU capabilities: Required for AI model training and machine learning computations.
- Camera Module: Provided image capture for precise waste classification.
- Weight Sensors: Enables accurate object detection and weight-based sorting.
- Raspberry Pi: Provides computing power for local AI inference and data processing.
- Wireless Module: Enables real-time data transmission and remote monitoring.
- Proximity Sensors: Detects or sense the approach or presence of nearby objects.
- Servomotor: Automates the lid opening/closing.
- Power Supply
- Dustbin + Frame

5.2. Development Tools

- Python: Primary language for AI/ML model development.
- TensorFlow/PyTorch: Libraries for building and training neural networks.
- OpenCV: Computer vision processing for waste image recognition.
- Scikit-learn: ML model evaluation and pre-processing.
- Django: Framework for building backend services.
- React JS: Framework for building frontend services.
- Figma: Tool for making diagrams.
- Balsamiq: Tool for making wireframes of the web application.

6. Review of similar project

The WasteWise project, which was chosen as the object of study, concerns the application of IoT and AI in waste management, as well as a comparable project, namely the **Smart Waste Management System (SWMS)**. WasteWise project would seek to respond to them by establishing a smart dustbin that incorporates artificial intelligence into waste type recognition and tracking in real-time. In the same manner, the Smart Waste Management System (SWMS) utilizes technology to enhance the cabinet liners methods covering waste collection and sorting. This segment of the report will consider both projects side by side according to the goal and objectives, approaches, characteristics, anticipated result, and implications.

Link for the Research Paper: SWMS Project Research Paper

6.1. Comparison Table

Table 1: Comparison Table between SWMS and Wastewise

Feature/Aspect	**WasteWise**	**SWMS**
Objective	To develop an intelligent waste management system using AI and IoT for efficient classification and monitoring of waste.	To optimize waste collection routes and improve sorting efficiency using sensor data.
Technology Utilized	IoT, AI for automated waste classification and real-time monitoring.	IoT sensors for fill-level detection and route optimization algorithms.
Key Features	- Automated waste classification - Real-time monitoring via web application - User-friendly interface - Error detection mechanism	- Sensors for bin fill-level detection - Route optimization for collection trucks - Mobile app for user interaction

Expected Outcomes	- Improved waste segregation accuracy - Increased recycling rates - Reduced landfill pollution - Enhanced user engagement in waste management practices	- Reduced operational costs for waste collection - Increased efficiency in collection routes - Better overall waste management through data analytics
Impact on Environment	- Decrease in landfill waste by 40-50% - Reduction of greenhouse gas emissions from landfills by up to 30% - Prevention of soil and groundwater contamination	- Minimization of fuel consumption due to optimized routes - Reduction of emissions from collection trucks - Improved recycling rates through better sorting
Target Audience	Municipalities, households, environmental organizations in developing countries.	Municipalities, waste management companies, urban planners.

6.2. Analysis of two projects

6.2.1. Similarities

- **Technological Integration:** In both the projects, IoT technology is used to improve the aspects of waste management.
- **Environmental Focus:** Both of the projects are designed in a way to attempt to cut down on wasted impact on the environment, whether it involves better organization of waste disposal, or designing a more efficient way of collection of wastes.
- **User Engagement:** For increased public participations in waste management, the two systems offer users easy to use interfaces.

6.2.2. Differences

- **Core Functionality:** WasteWise is mainly concerned with proper disposing of waste from numerous disposal spots, and SWMS is a means of organizing collection based on input data.
- **Methodology**: WasteWise deploys artificial intelligence algorithms in classification while SWMS relies on receiving data from the sensors in its determination of collection routes.
- **Expected Outcomes**: WasteWise is designed primarily for increasing the accuracy of segregation and recycling percent whereas SWMS focus on concerns of operations and costs.

7. Development to date

7.1. Gantt Chart

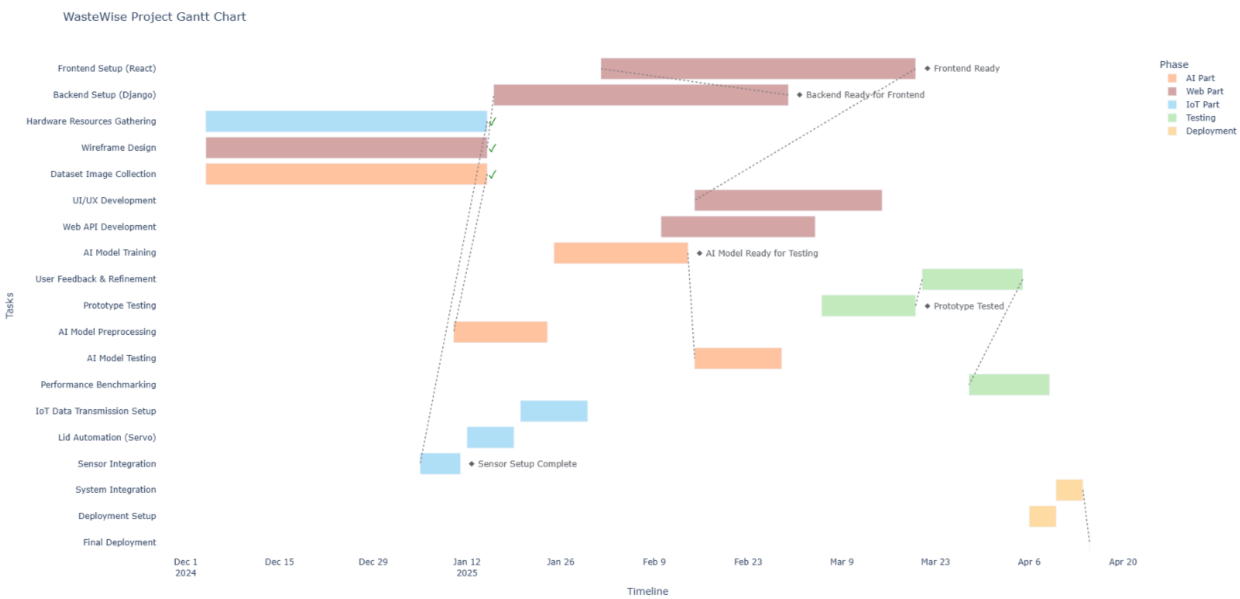


Figure 4: Gantt Chart

7.1.1. Detailed Breakdown

Table 2: Detailed breakdown of Gantt Chart

Phase	Task	Dependencies	Start Date	End Date	Duration (Days)	Status
AI Part	Dataset Image Collection	None	12/4/2024	1/15/2025	42	Complete
	AI Model Pre-processing	Dataset Image Collection	1/10/2025	1/24/2025	15	In Progress
	AI Model Training	AI Model Pre-processing	1/25/2025	2/14/2025	20	Pending
	AI Model Testing	AI Model Training	2/15/2025	2/28/2025	14	Pending
IoT Part	Hardware Resources Gathering	None	12/4/2024	1/15/2025	42	Complete

	Sensor Integration	Hardware Resources Gathering	1/5/2025	1/11/2025	6	Pending
	Lid Automation (Servo)	Sensor Integration	1/12/2025	1/19/2025	7	Pending
	IoT Data Transmission Setup	Lid Automation (Servo)	1/20/2025	1/30/2025	10	Pending
Web Part	Wireframe Design	None	12/4/2024	1/15/2025	42	Complete
	Backend Setup (Django)	Wireframe Design	1/16/2025	3/1/2025	45	Pending
	Frontend Setup (React)	Backend Setup (Django)	2/1/2025	3/20/2025	48	Pending
	Web API Development	Frontend Setup (React)	2/10/2025	3/5/2025	23	Pending
	UI/UX Development	Frontend Setup (React)	2/15/2025	3/15/2025	30	Pending
Testing	Prototype Testing	AI Model Testing, UI/UX Development	3/6/2025	3/20/2025	14	Pending
	User Feedback & Refinement	Prototype Testing	3/21/2025	4/5/2025	15	Pending

	Performance Benchmarking	User Feedback & Refinement	3/28/2025	4/9/2025	12	Pending
Deployment	Deployment Setup	Performance Benchmarking	4/6/2025	4/10/2025	5	Pending
	System Integration	Deployment Setup	4/10/2025	4/14/2025	5	Pending
	Final Deployment	System Integration	4/15/2025	4/15/2025	1	Pending

7.2. Flowchart

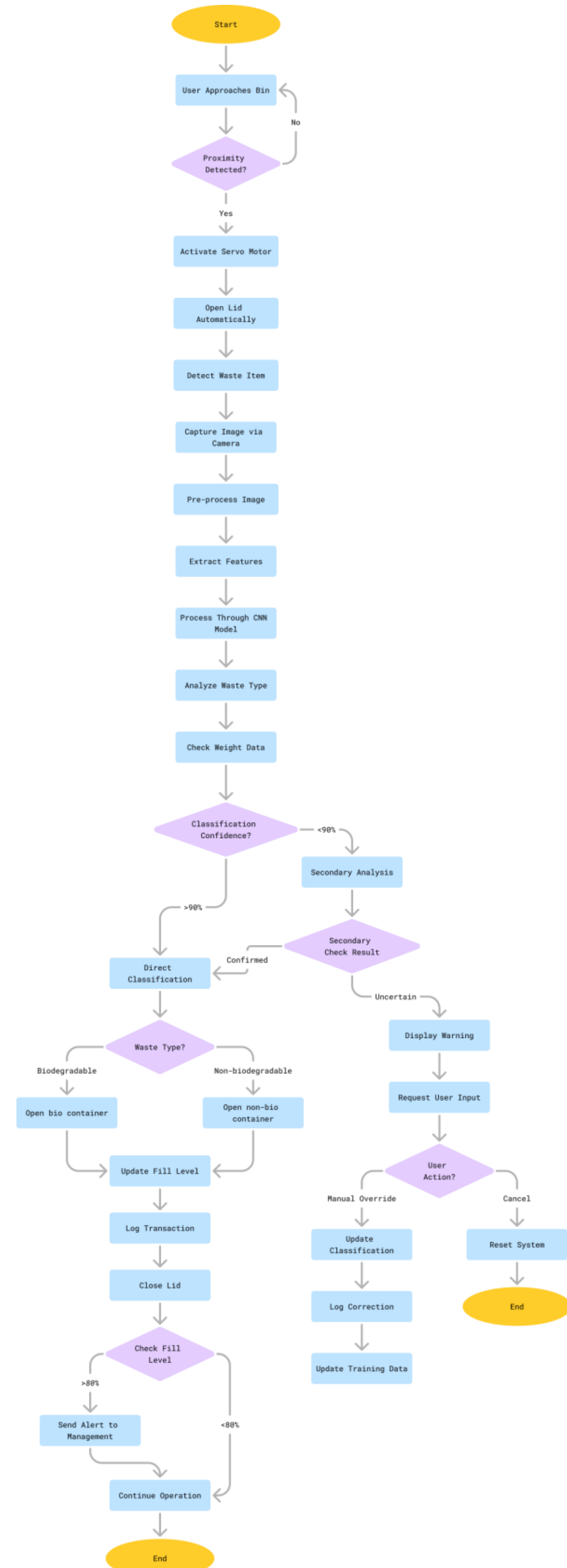


Figure 5: Flowchart of Wastewise

7.3. Use Case

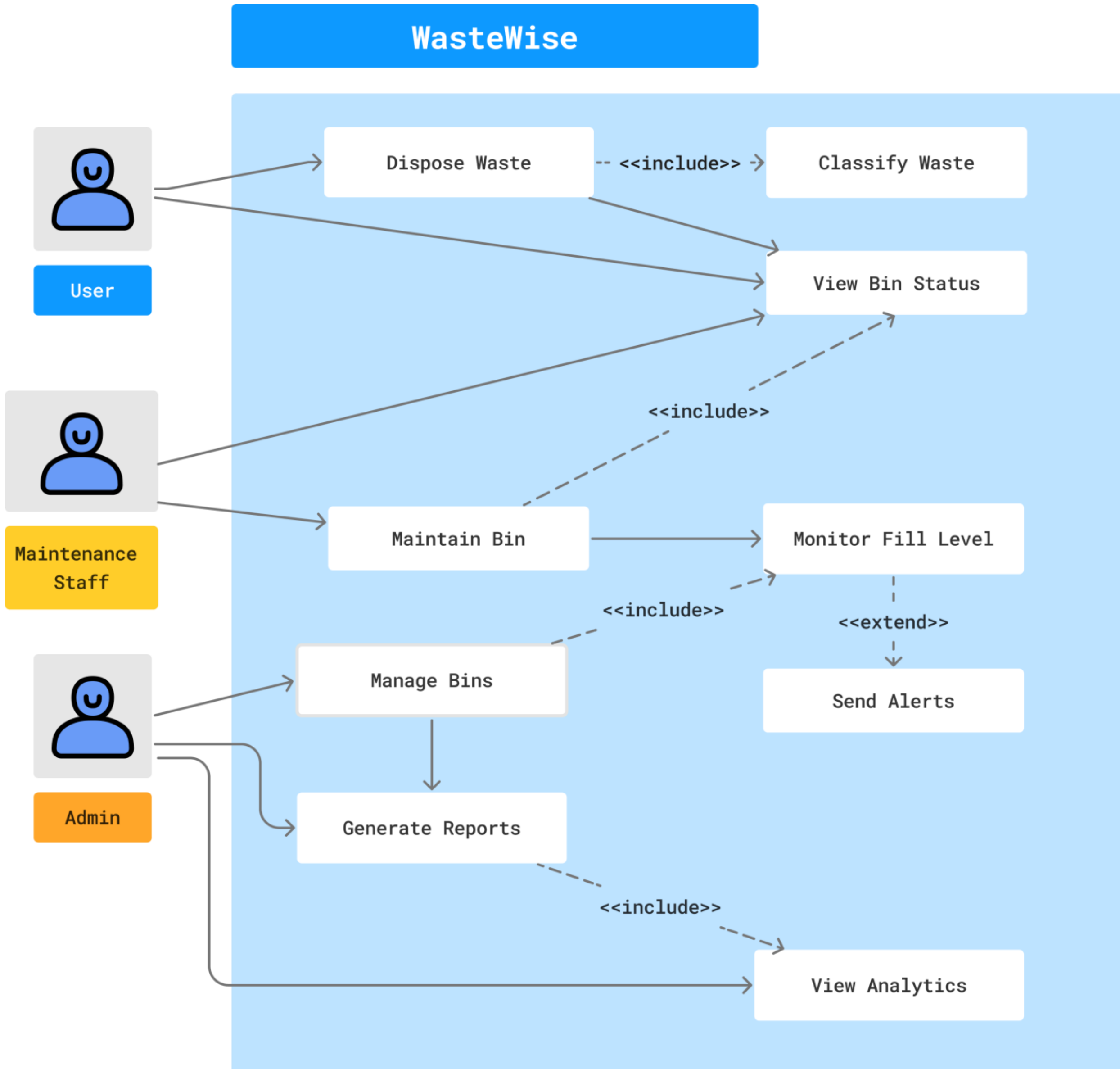


Figure 6: Use Case Diagram of Wastewise

7.4. Entity Relationship Diagram (ERD)

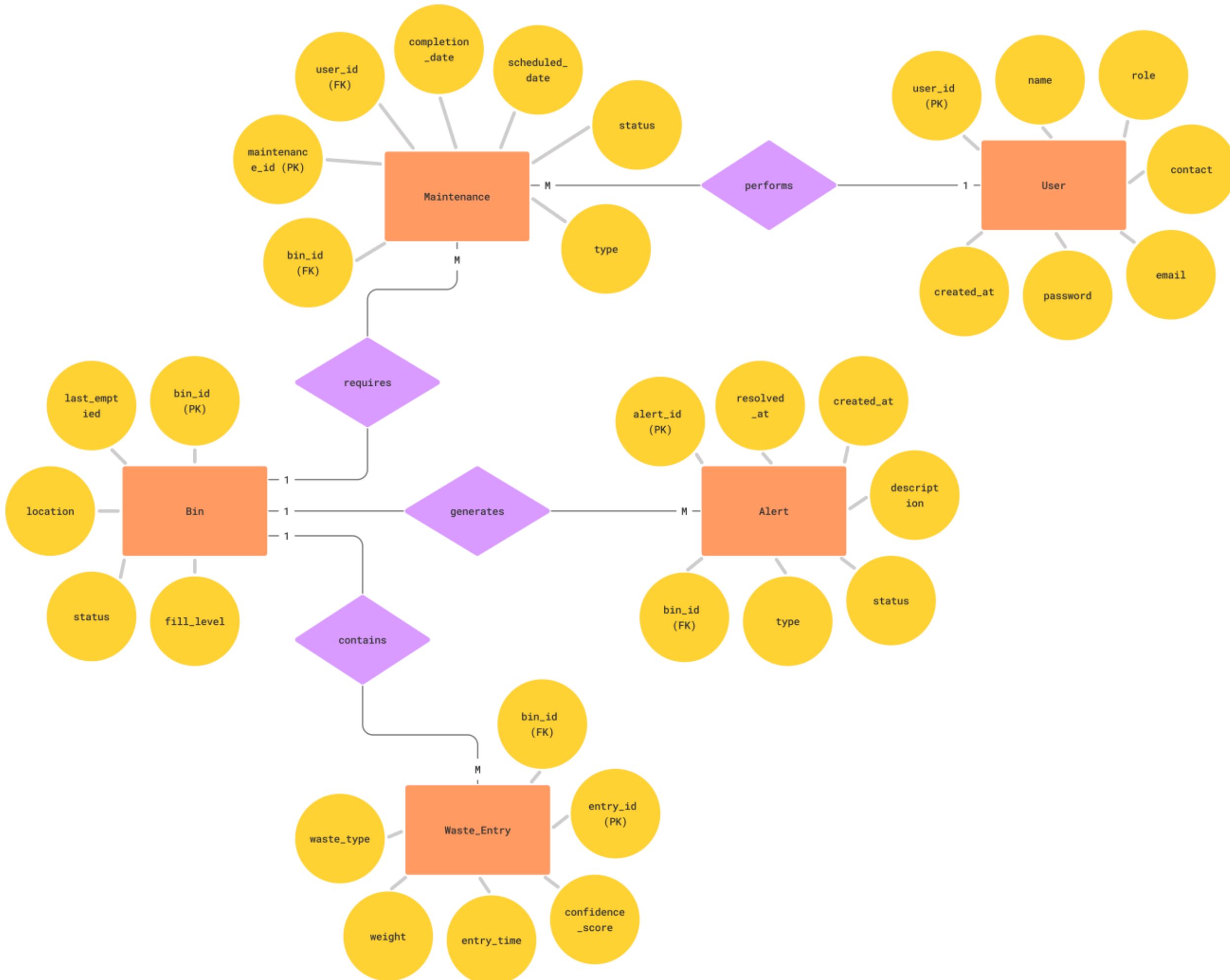


Figure 7: ERD of Wastewise

7.5. Software Requirements Gathering (SRS)

The SRS is kept in the appendix section at the end of the document.

Link to the SRS: SRS

7.6. Wireframe

7.6.1. Register User Page

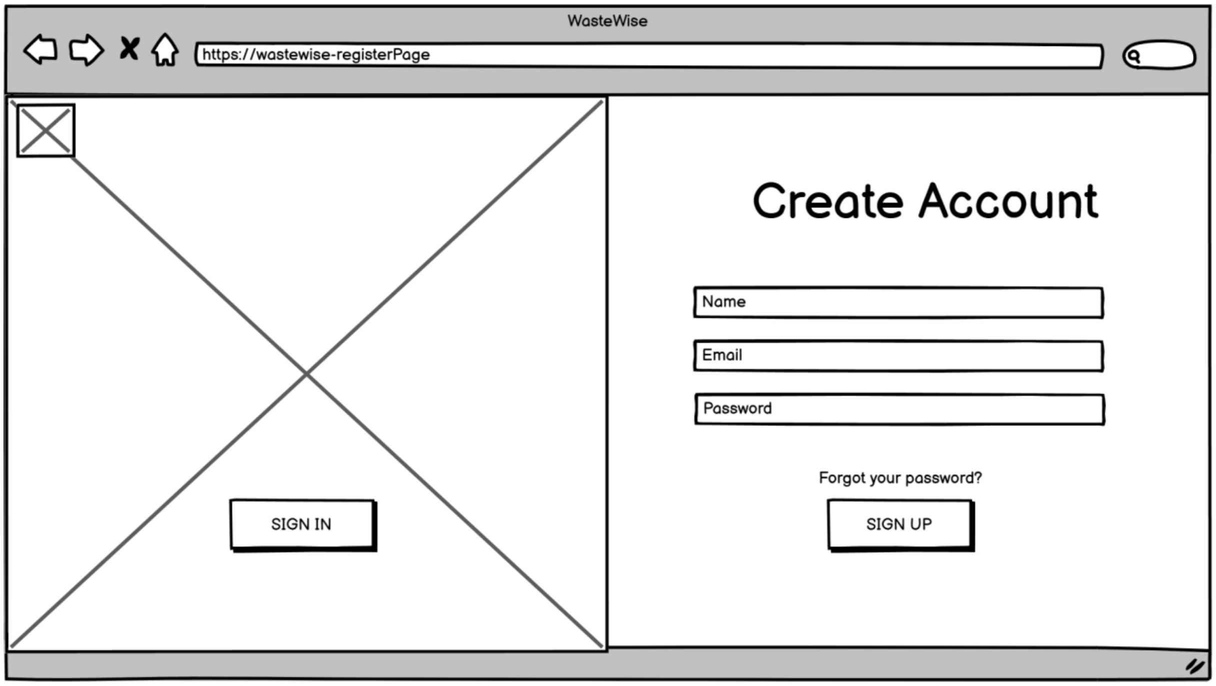


Figure 8: Wireframe of Register User Page

7.6.2. Login User Page

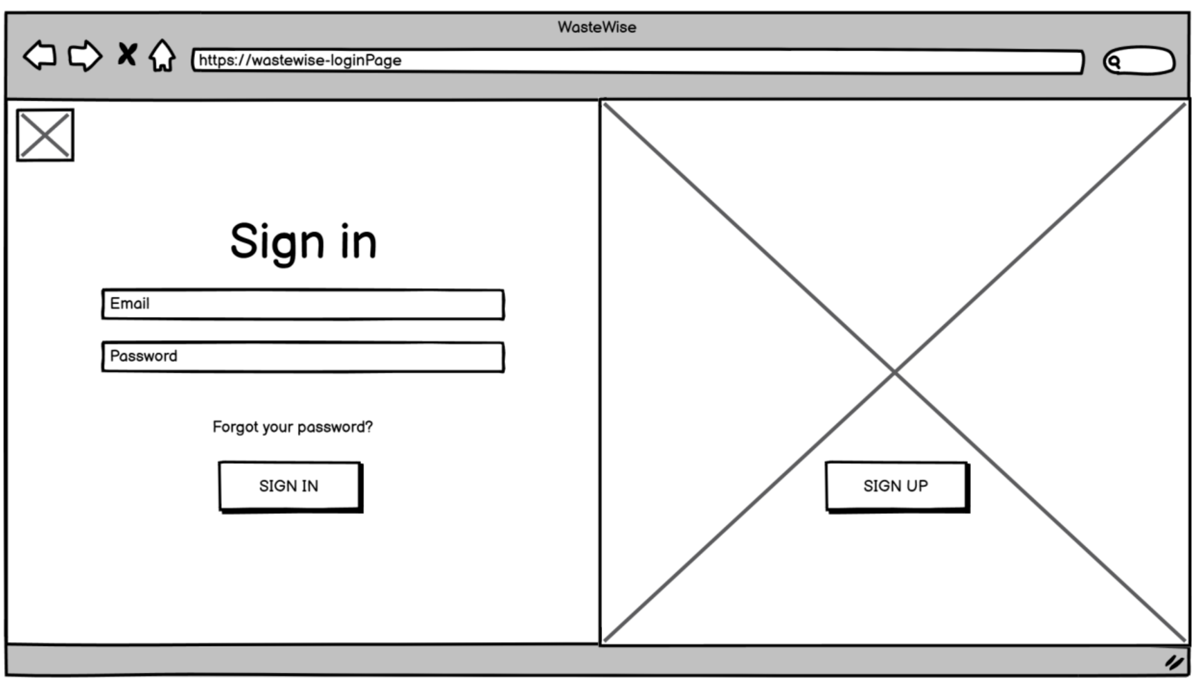


Figure 9: Wireframe of Login User Page

7.6.3. Landing Page

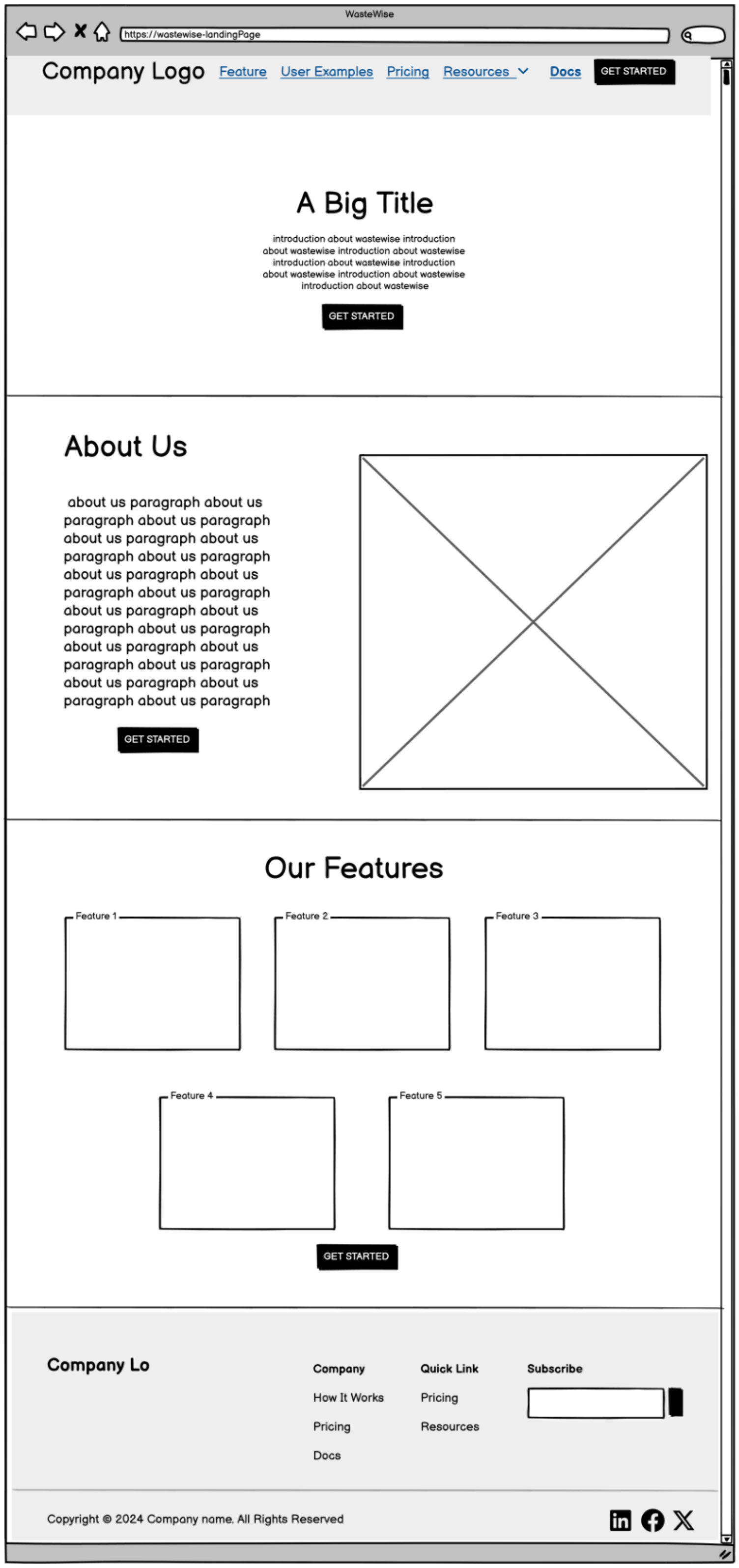


Figure 10: Wireframe of Landing Page

7.6.4. Admin Dashboard

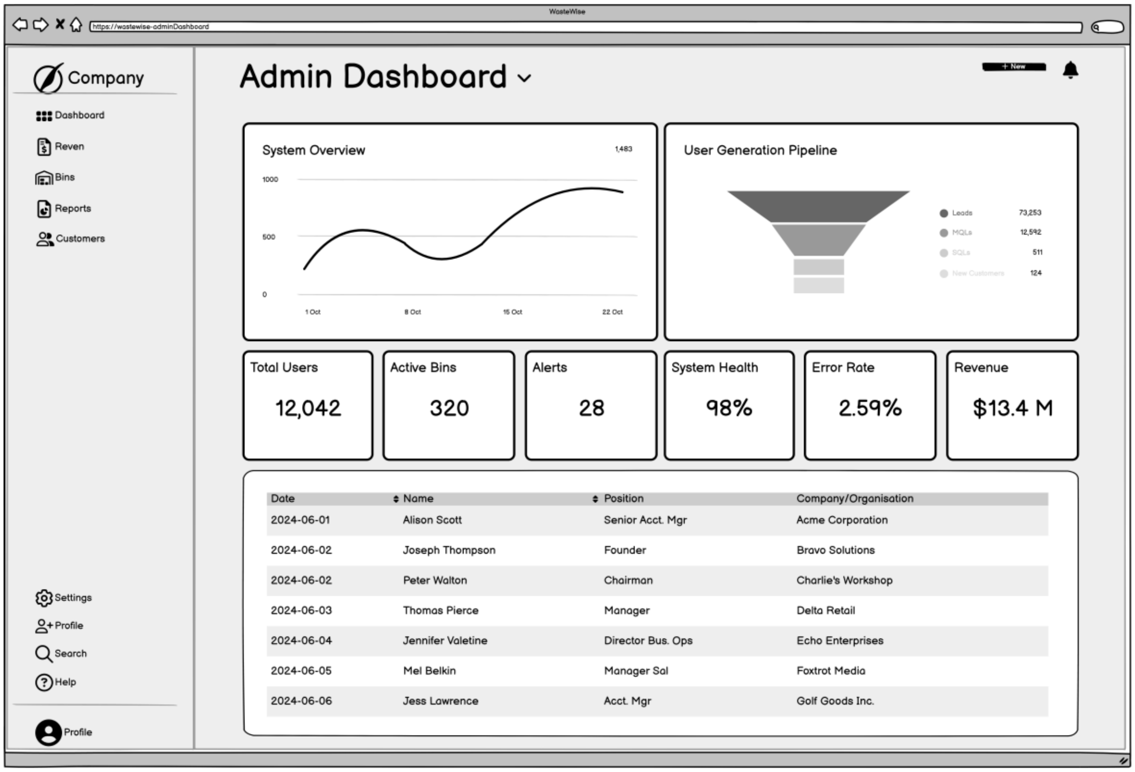


Figure 11: Wireframe of Admin Dashboard

7.6.5. User Dashboard

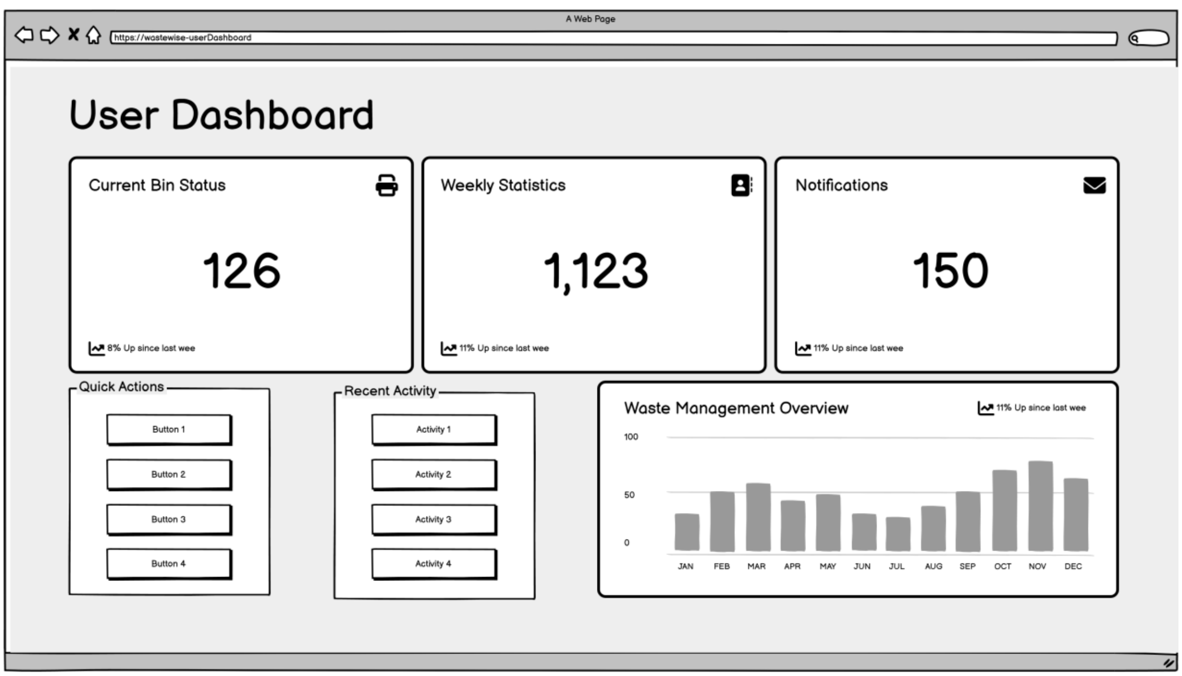


Figure 12: Wireframe of User Dashboard

7.6.6. Bin Management

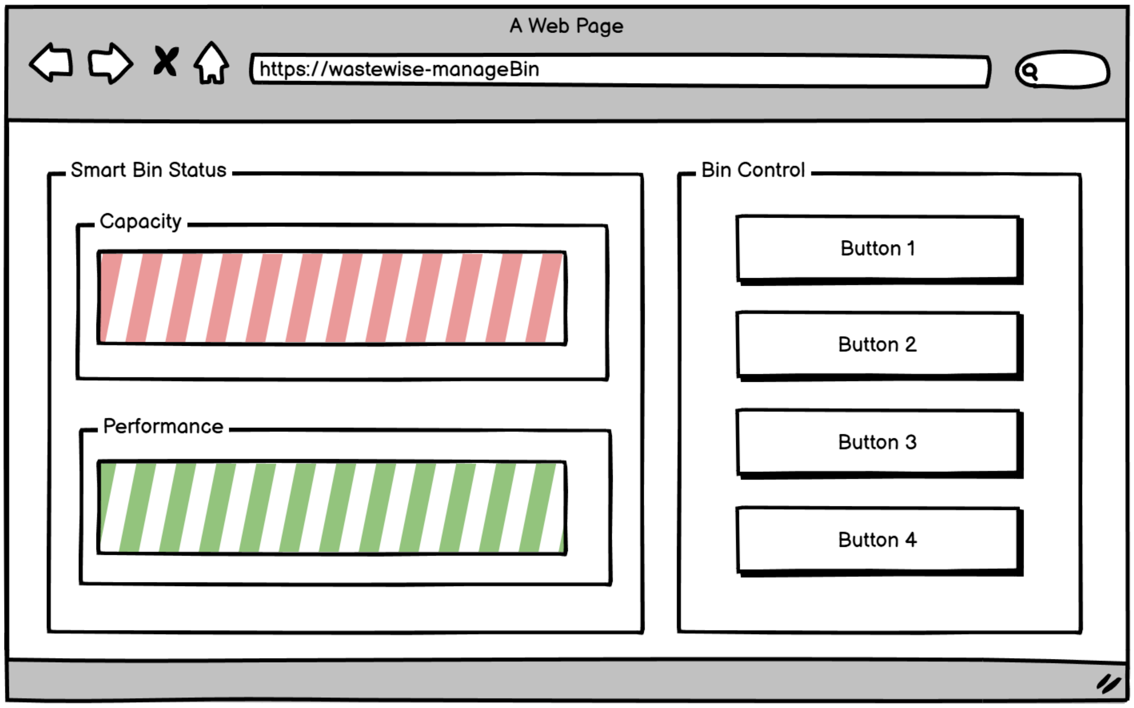


Figure 13: Wireframe of Bin Management

7.7. Sequence Diagram of the Whole System

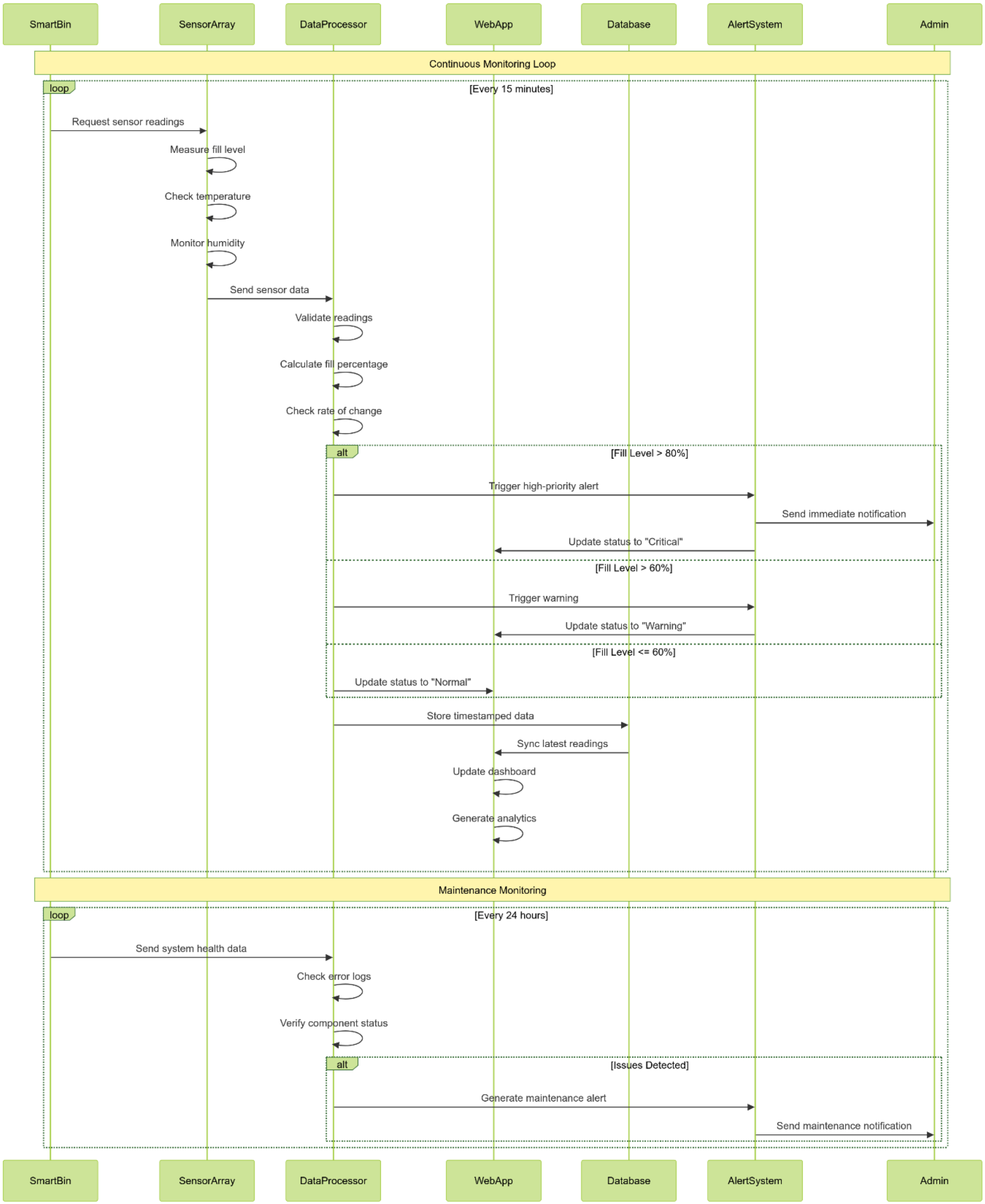


Figure 14: Sequence Diagram for WasteWise System

7.7.1. Sequence Diagram for Waste Classification

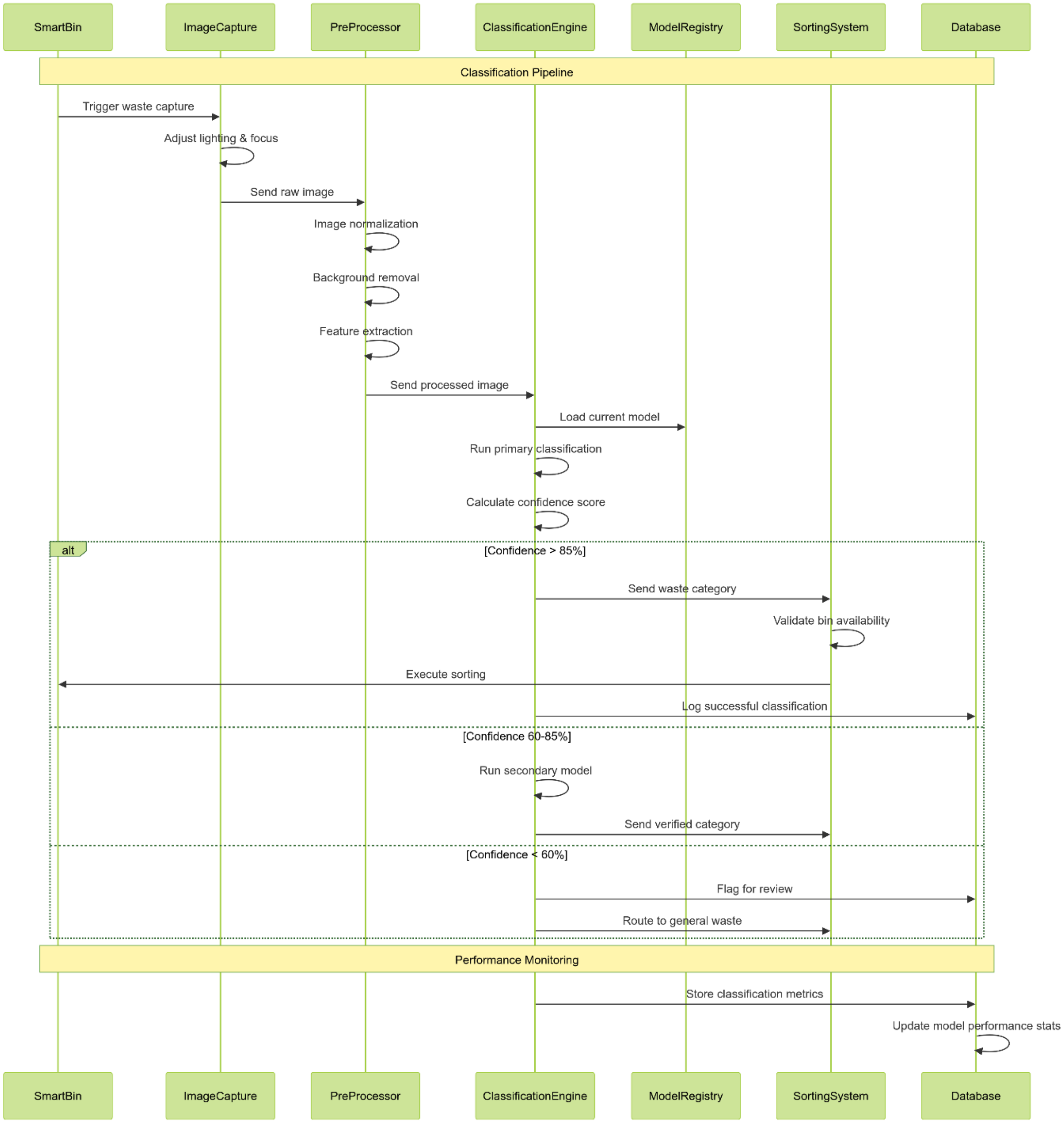


Figure 15: Sequence Diagram for waste classification

7.7.2. Sequence Diagram for Bin Management

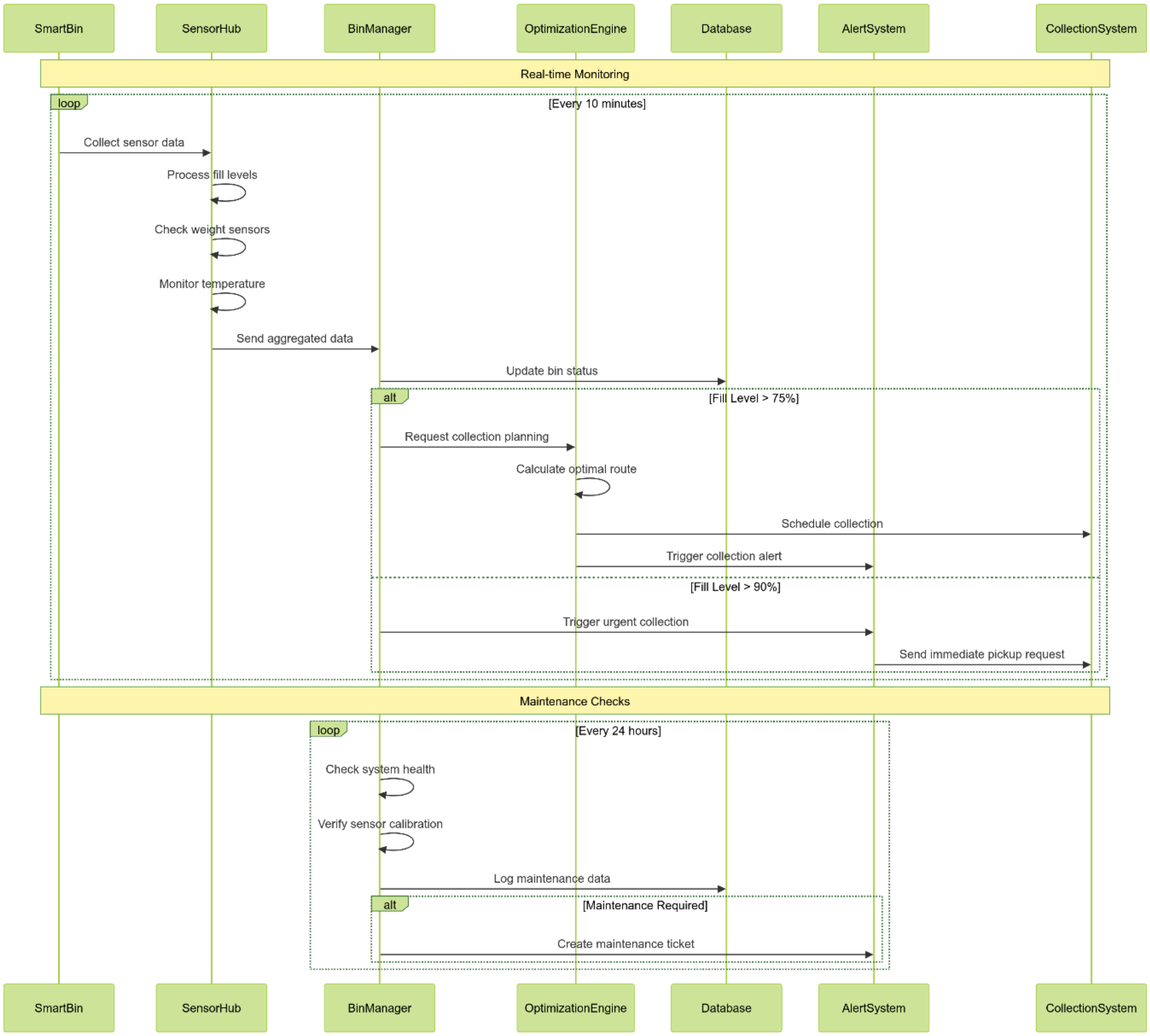


Figure 16: Sequence Diagram for bin management

7.7.3. Sequence Diagram for Monitoring and Analytics System

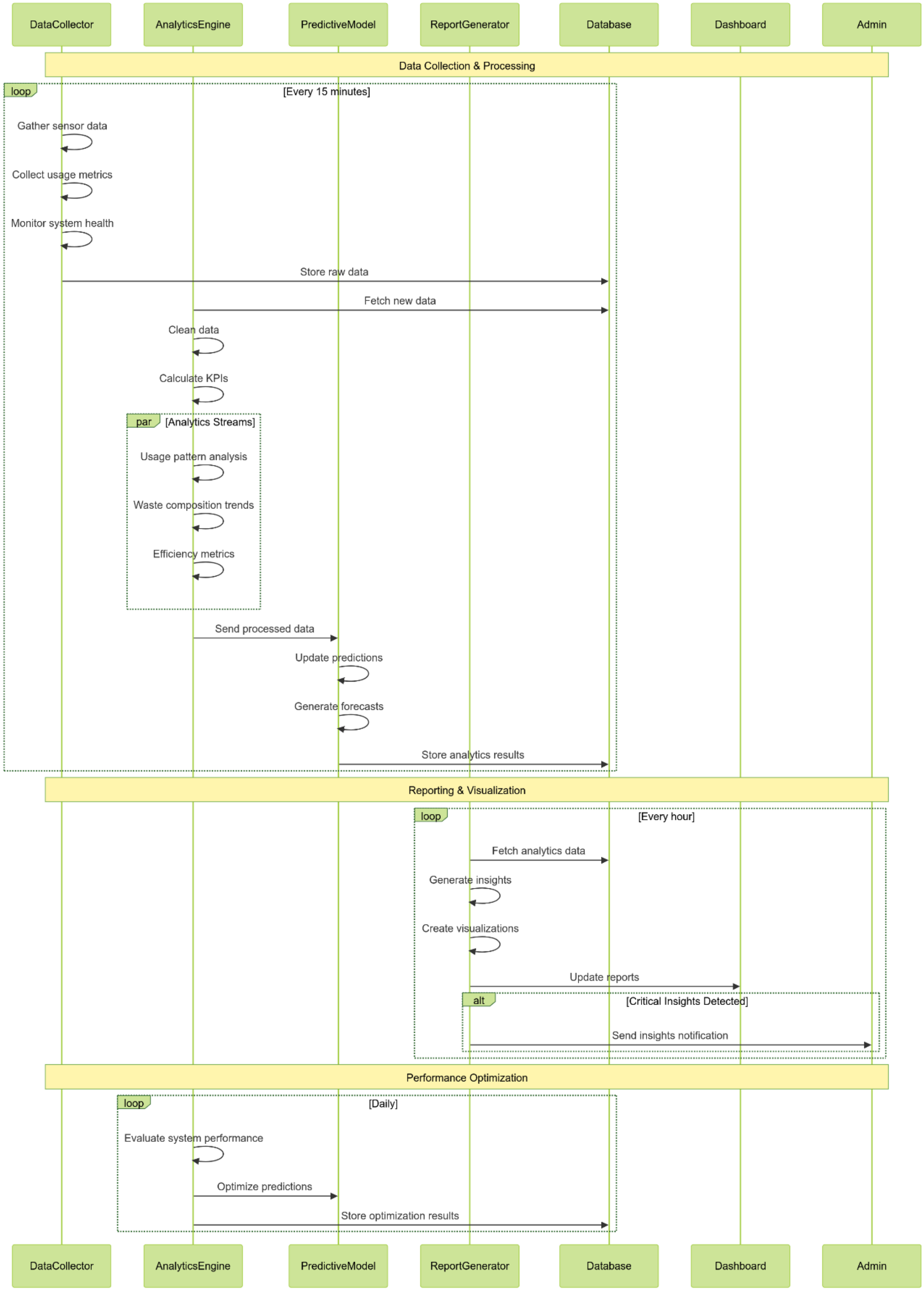


Figure 17: Sequence Diagram for monitoring and analytics system

7.8. Data Flow Diagram (DFD)

7.8.1. Level 0 DFD

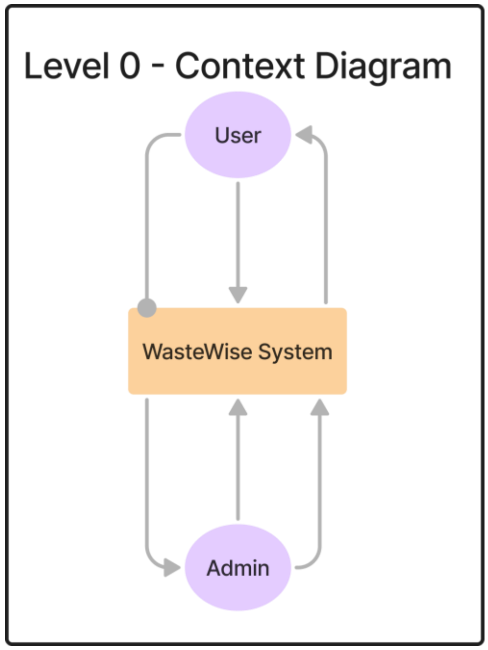


Figure 18: Level 0 Context DFD

7.8.2. Level 1 DFD

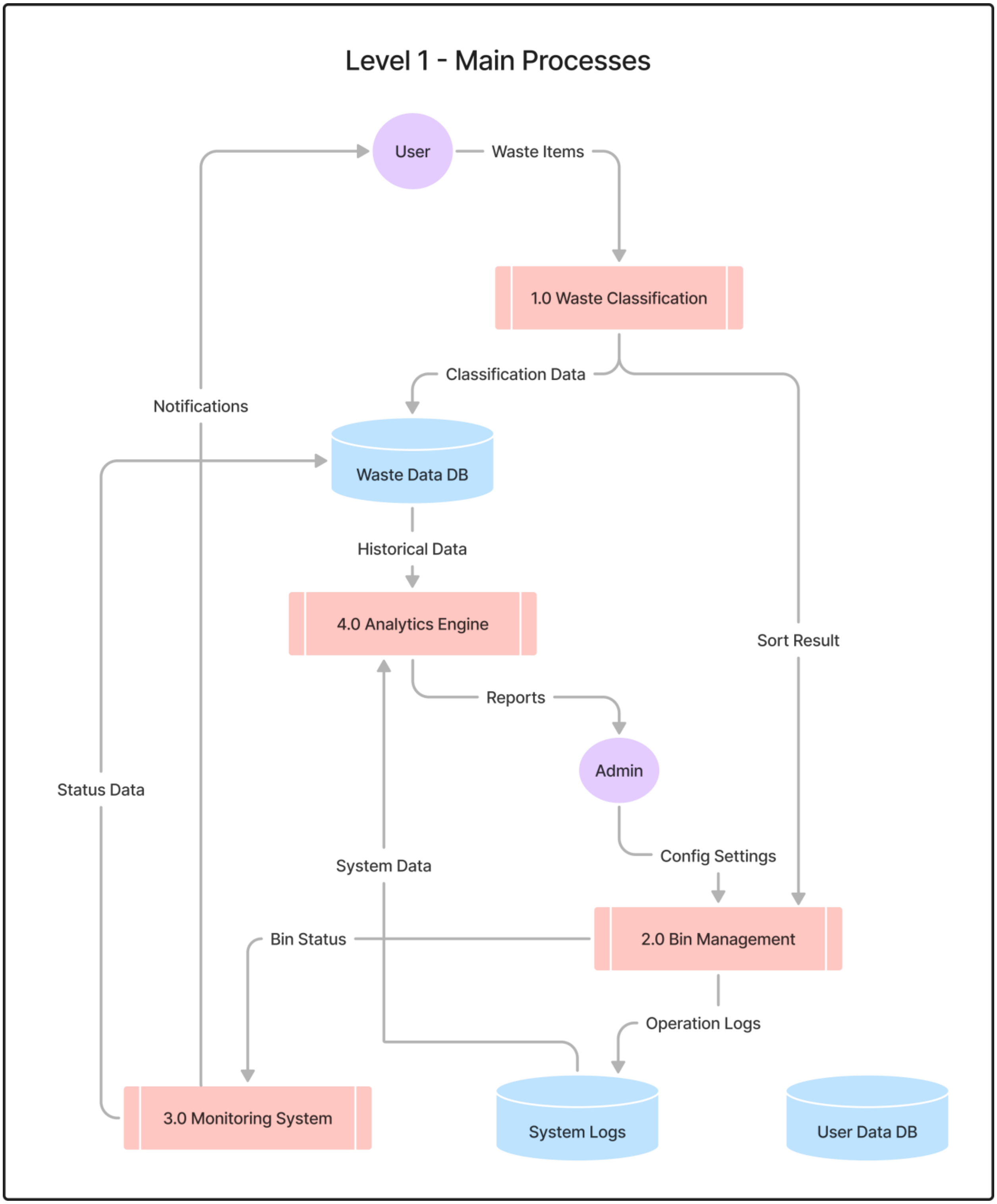


Figure 19: Level 1 DFD

7.8.3. Level 2 DFD – 1.0 Waste Classification

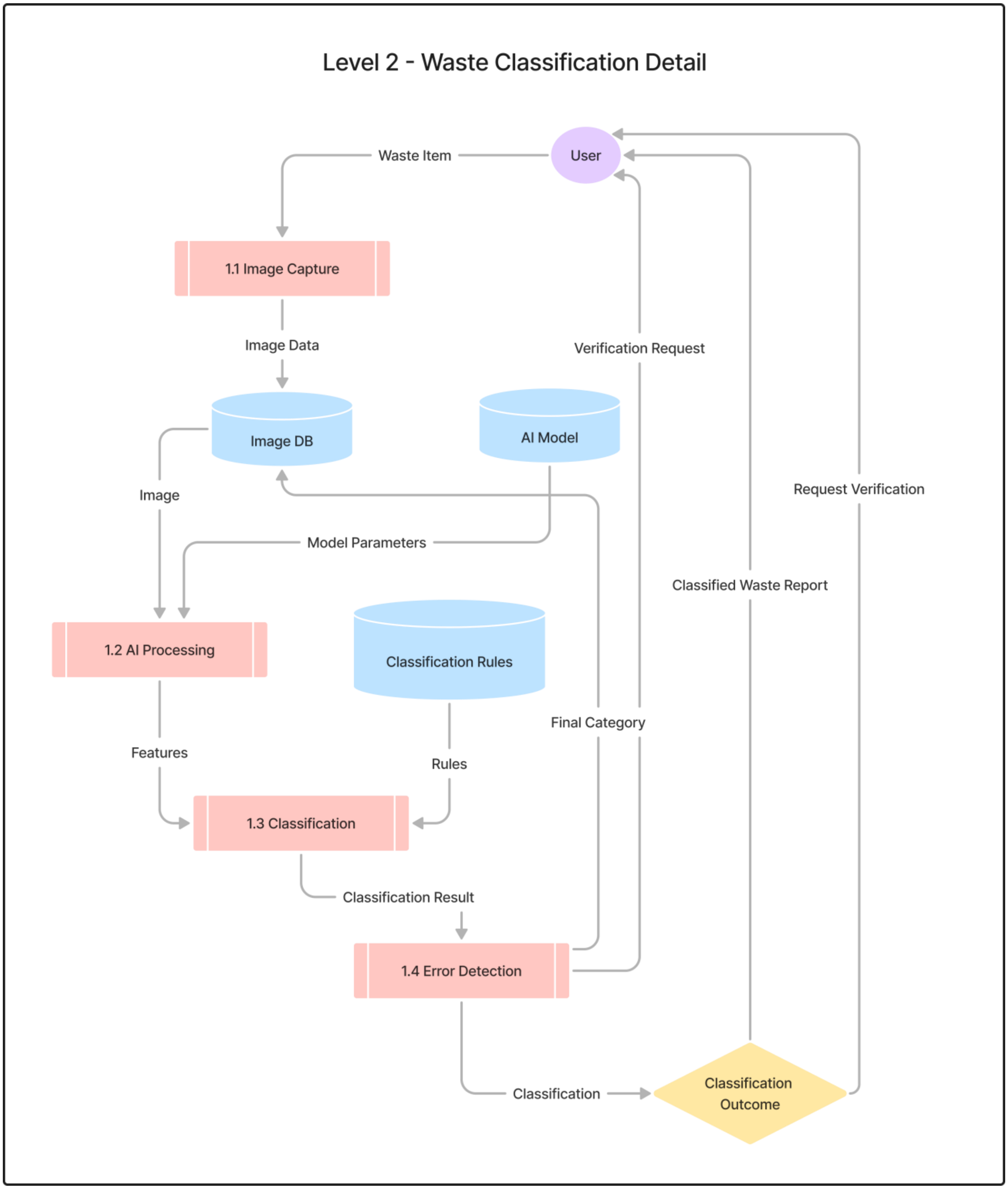


Figure 20: Level 2 DFD for Waste Management

7.8.4. Level 2 DFD – 2.0 Bin Management

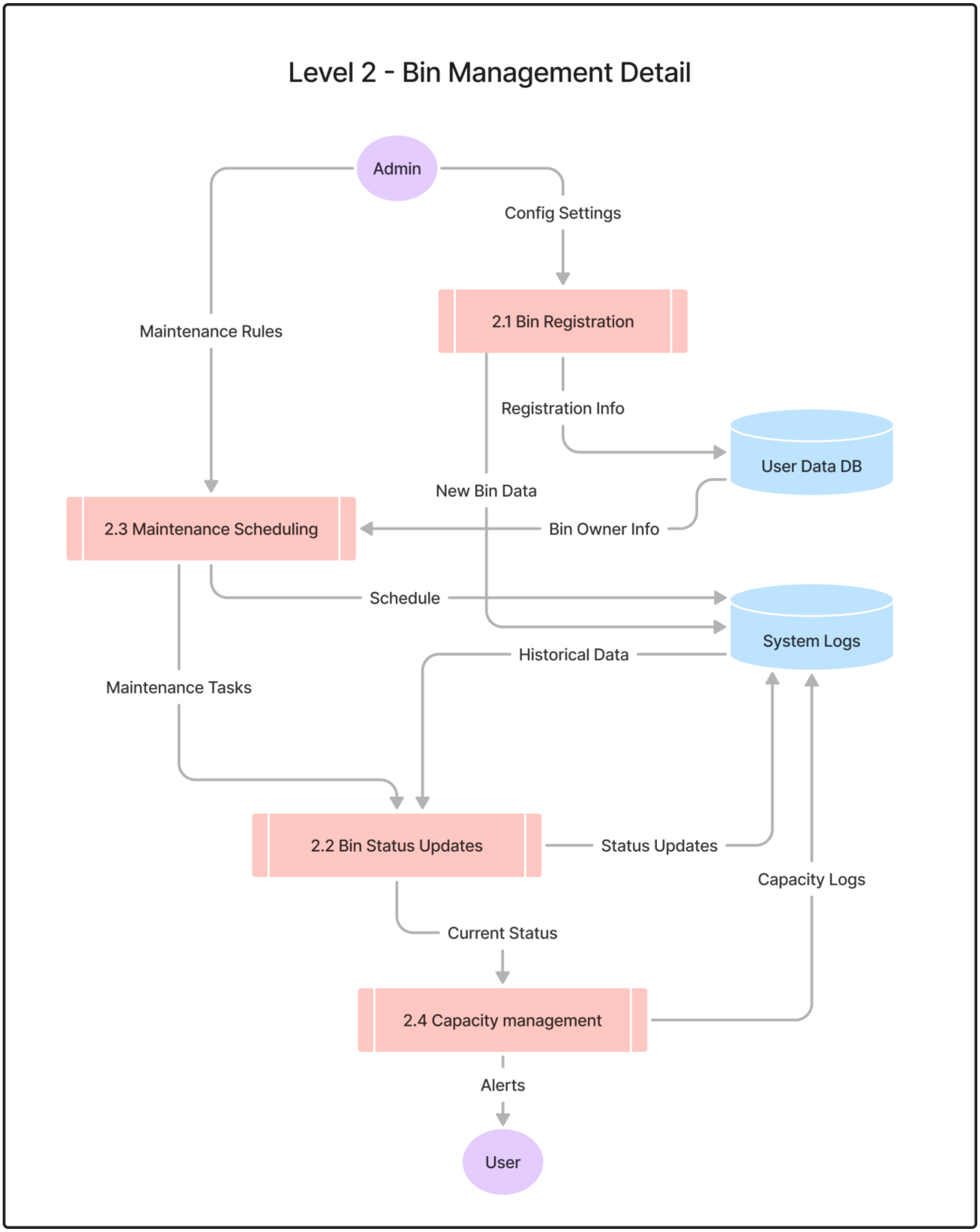


Figure 21: Level 2 DFD for Bin Management

7.8.5. Level 2 DFD – 3.0 Monitoring System

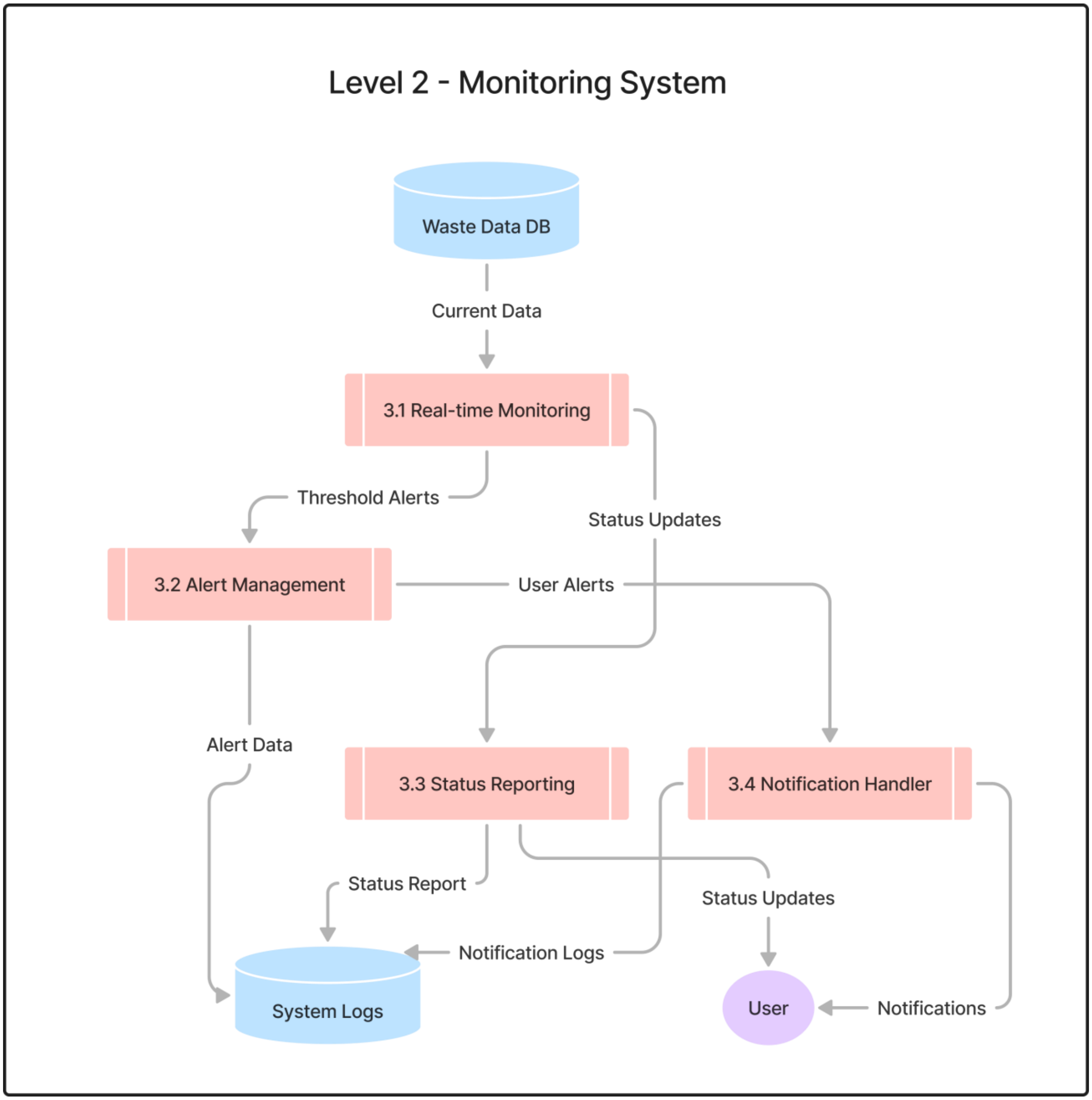


Figure 22: Level 2 DFD for Monitoring System

7.8.6. Level 2 DFD – 4.0 Analytics Engine

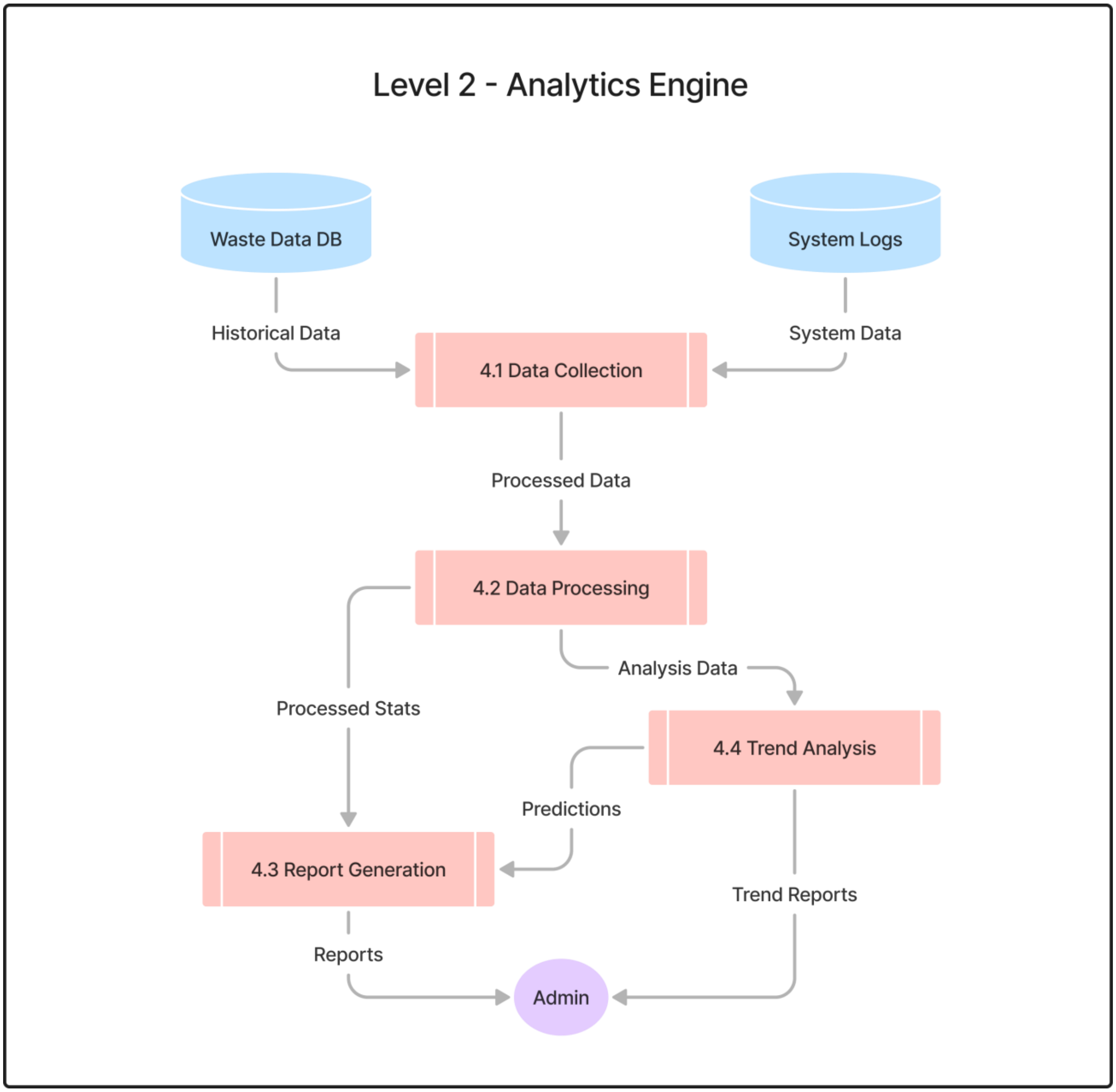


Figure 23: Level 2 DFD for Analytics Engine

7.9. System Architecture Diagram

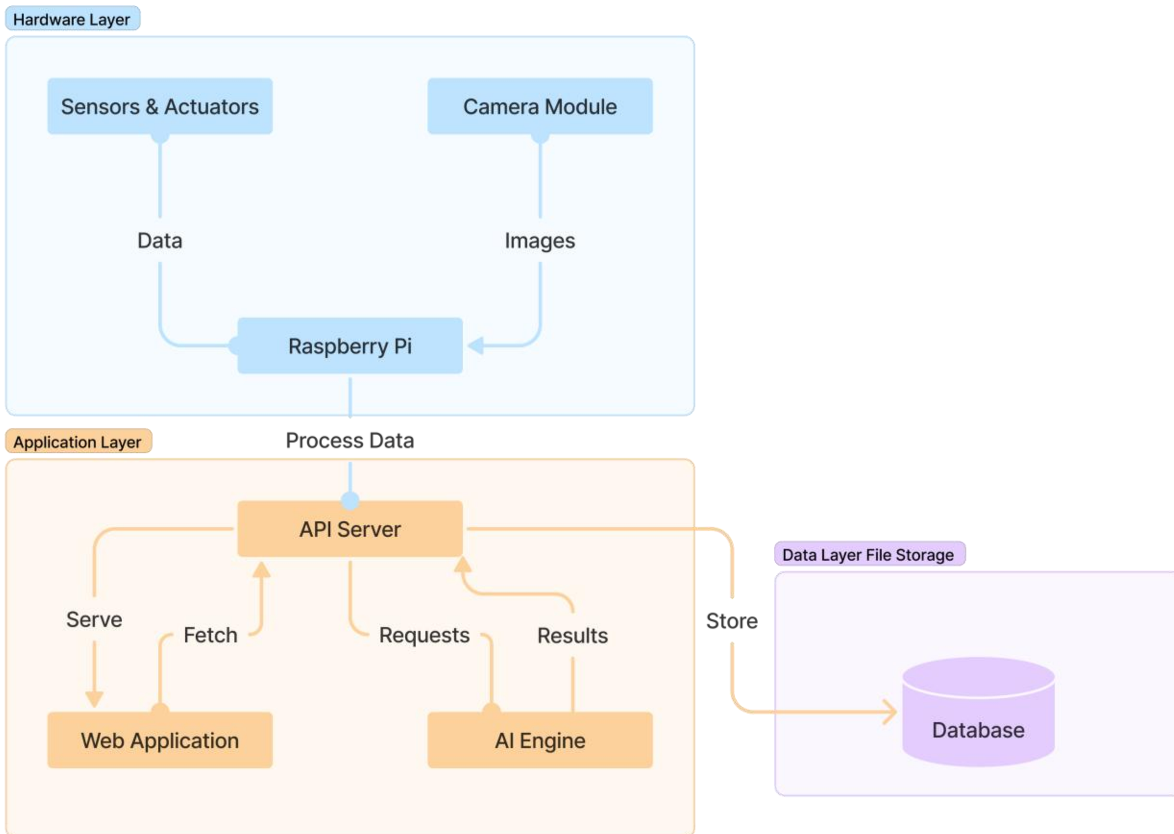


Figure 24: System Architecture Diagram of WasteWise

7.10. Developed Features

7.10.1. Completed Features

- AI Component
    - Dataset image collection is completed.
- IoT Component
    - Hardware resources gathering is completed.
- Web Component
    - Wireframe designing is completed.

7.10.2. In-Process Features

- AI Component
    - Model pre-processing is the next in pipeline.
    - Model training
    - Model testing
- IoT Component
    - Sensor integration
    - Lid automation
    - Data transmission setup
- Web Component
    - Backend development using Django.
    - Frontend development using React.
    - API Development
    - UI/UX implementation

7.11. Analysis of Progress

7.11.1. Overview of Current Status

The project is currently in initial development phase with about approximately 16% completion. 3 out of the 19 planned tasks are completed till date:

- AI Component: 25% complete (1/4 tasks)
- IoT Component: 25% complete (1/4 tasks)

- Web Component: 20% complete (1/5 tasks)
- Testing & Deployment: Not yet started (0/6 tasks)

7.11.2. Comparison with the Project Plan

- Timeline Adherence:
  - Initial milestones are met as planned until December 2024.
  - The current progress aligns with the projected timeline.
  - There are no significant delays seen in completed sub-tasks.
  - The critical path activities are on time.
- Phase Progress:
  - The foundation phase was completed on schedule i.e., December 2024 – January 2025.
  - The development phase is starting as planned from January 2025.
  - The overall project is targeted to be completed by April 2025 which seems achievable.

7.11.3. Challenges Encountered

- Technical Challenges
  - The dataset required for AI training seemed quite complex.
  - The hardware components availability and compatibility were also a crucial challenge encountered.
  - The integration planning between different modules was a difficult task.
- Timeline Challenges
  - The overlapping development phases might need very careful resource allocation.
  - The dependencies between AI, IoT and Web components might be a factor for delay in task completion.
  - There are numerous parallel development tracks in the Gantt chart.

7.11.4. Successes and Achievements

- Major Milestones
  - The initial foundation phase was successfully completed.
  - The dataset collection was completed before the deadline.

   - Hardware resources gathering was done within the budget and schedule.
   - The wireframe design for web application was approved and completed.
- Process Achievements
   - Effective use of the control project schedule and determining the right sequence of the tasks.
   - Achievement of parallel development tracks.
   - Laid a very good basic ground for the subsequent phases to be implemented.

7.11.5. Analysis of Development Activities

- Current Focus Areas:
   - AI: The next step is model pre-processing.
   - IoT: Beginning sensor integration.
   - Web: Learning and starting backend development side by side.
- Resource Utilization:
   - Purchases and acquisitions made.
   - Technical infrastructure developed.

7.11.6. Action Plans

Table 3: Action Plans

Immediate Actions (Next 30 Days)	**Medium-term Actions (60-90 Days)**	**Long-term Actions (90+ Days)**
Begin AI model pre-processing	Complete AI model training	System integration
Initiate sensor integration	Finish IoT component integration	Testing and optimization
Start backend development	Develop core web functionality	Deployment preparation

7.11.7. Reflection on methodology

The evolutionary prototyping methodology has proven effective because this method allows the development of these systems to be done simultaneously on AI, IoT, and Web components. It also allows the confirmation of various vital parts during the initial stages of the project. It supports the cyclic enhancement of the development process and fosters risk reduction with the help of initial testing.

7.11.8. Progress Table

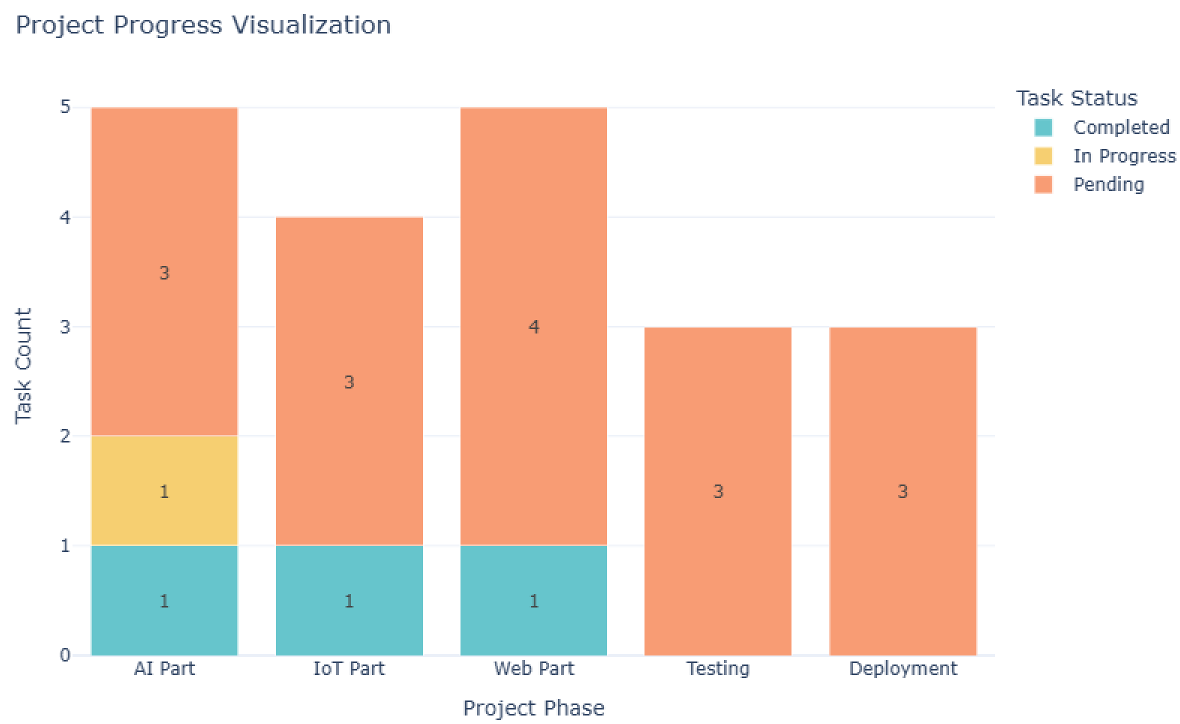


Figure 25: Project Progress Visualization

Table 4: Project Progress Table

Phase	Total Tasks	Completed	In Progress	Pending	Completion %
AI Part	4	1	1	3	25%
IoT Part	4	1	0	3	25%
Web Part	5	1	0	4	20%
Testing	3	0	0	3	0%
Deployment	3	0	0	3	0%
Overall	**19**	**3**	**0**	**16**	**15.80%**

8. Future Work

Based on the evolutionary prototyping methodology selected for the WasteWise project, the future work will focus on iterative development and continuous enhancement across multiple phases:

Phase 1: Core System Refinement

- **AI Model Optimisation**
  - Include additional waste samples to the training dataset.
  - Another suggested tactic in boosting up the classification accuracy is to enable the transfer learning methods.
  - Work on creating system to monitor performance of models and create corresponding systems for model retraining.
  - Introduce a way for classifying wastes beyond just binary categorization.
- **IoT System Refinement**
  - One of the proposed steps is refining the algorithms that utilize the data received from sensors for more efficient waste identification.
  - Adopt power management strategies for long lasting batteries.
  - Find ways to have precautions for the failure of the hardware components.
  - Get the system capable for working when the network is down.
- **Web Application Development**
  - Adopt mobile compatibility and responsiveness.
  - Add the outcome that the current views based advanced analytics dashboard with customizable metric.
  - Create bin status update service for real time status notification.
  - Set service user feedback for facilitation of continuous service improvement.

8.1. Future Research Direction

- Exploratory research on sophisticated approaches to the use of ML in waste sorting.
- Pattern of user behaviour in the disposal of wastes.
- Evaluation of environmental impact indicators.
- Studying integration of project to the smart city systems.
- Prospective research about the application of blockchain technology for tracking waste.

8.2. Potential Extensions

- Mobile Application Development
  - A native mobile application for iPhone and Android device.
  - Maintenance of functionality for offline areas
  - The real-time push notification about the collection of wastes
- Integration Capabilities
  - Interface for third party services.
  - Support for municipal waste management systems.
  - Data integration into the systems of the corresponding recycling facilities.

8.3. Success Metrics for Future Development

- The accomplishment of 95% waste classification accuracy.
- Reduction of contamination rates by 70%, of wastes.
- System uptime of 99.9%
- Using customer satisfaction above 90%.
- All operations should take no more than less than one second of processing time.

This future work plan will be reviewed and updated regularly from the user feedback, development in technology and other new requirements will be followed as per the model of evolutionary prototyping methodology.

9. Appendix

9.1. Pre-Survey Analysis

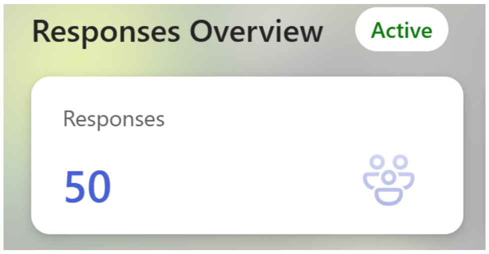


Figure 26: Pre-survey response overview

The survey within the WasteWise Project received fifty responses to check the respondents' awareness of waste management and further, the perceptions of smart waste. The demographic configuration reveals 70% of the consumers within the age bracket of 18-24 years, of the 80% consumers are from the urban background many of which live in individual houses (50%) and shared houses or apartments (25%). This means that the targeted audience is saturated with technology and will respond well to smart solutions.

About waste disposal, 45% said that they do not practice segregation, the other 40% segregate between biodegradable & non-biodegradable waste. Disposal frequency is principally concerned with 2-3 times weekly (50%), with daily disposal (25%) reflecting the need for heavier duty solutions. Biggest problems are time (32%), equipment (28%), and uncertainty regarding types of waste (25%).

Overall, adoption of smart dustbin is relatively high with 80% of the respondents willing to adopt (Yes/Maybe) dustbin. Users are relatively 'tech-savvy' and 'average' on tech comfort scale 4/5 while exhibit a good environmental literacy. The four features considered to be most wanted are the ability to sort the streams automatically, 85 percent; enjoy real-time monitoring, 82 percent; and mobile notifications, 75 percent. All the other issues are of concern if not in order as follows: reliability (35%), maintenance (30%), and privacy (20%).

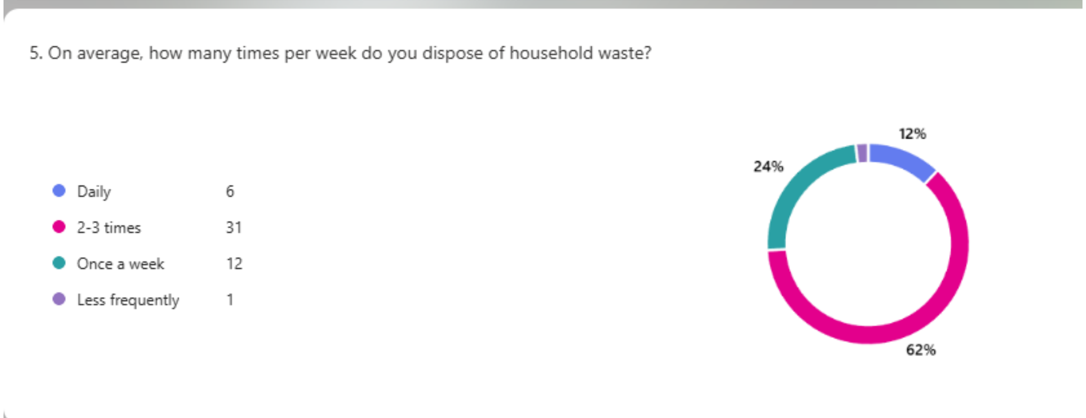
Training preference therefore is in the form of video tutorials closely followed by live demonstrations. The outcomes of the survey show that durability, cost and easy maintenance are key considerations among users. Environmental concern leads to consideration for enhanced waste management, 44% for an ability to pay for smart solutions but 34% highly sensitive to cost implications indicating that they are only interested in sustainable innovations for waste management.

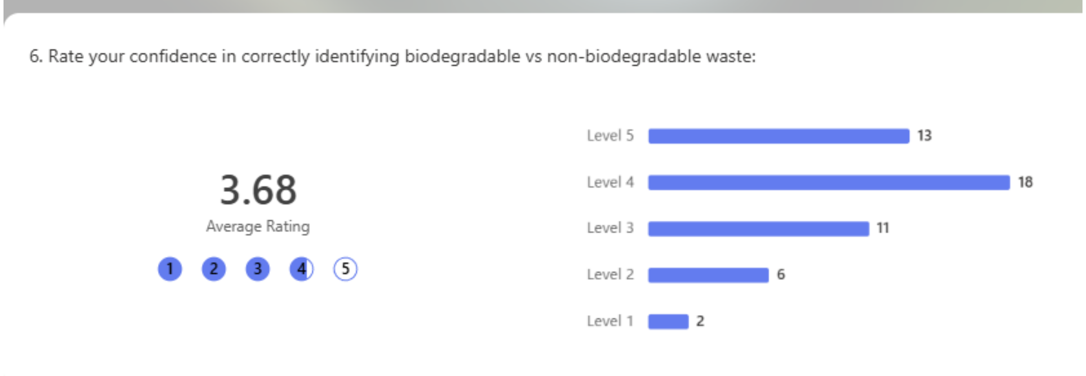
Recommendations: Focus on teaching the targeted urban households long-lasting, affordable designs, consider establishing video training, and respond to the maintenance questions. Think about requested options such as odour removal and notification of the full, to expand user base.

9.1.1. Evidence of pre-survey

Figure 27: Pre-survey (demographic info)


4. How do you currently segregate your household waste?
No segregation 23
Separate biodegradable/non-biodegradable 26
Separate recyclables 3
Other 0
6%
44%
50%


5. On average, how many times per week do you dispose of household waste?
Daily 6
2-3 times 31
Once a week 12
Less frequently 1
12%
24%
62%


6. Rate your confidence in correctly identifying biodegradable vs non-biodegradable waste:
3.68
Average Rating
1 2 3 4 5
Level 5 13
Level 4 18
Level 3 11
Level 2 6
Level 1 2

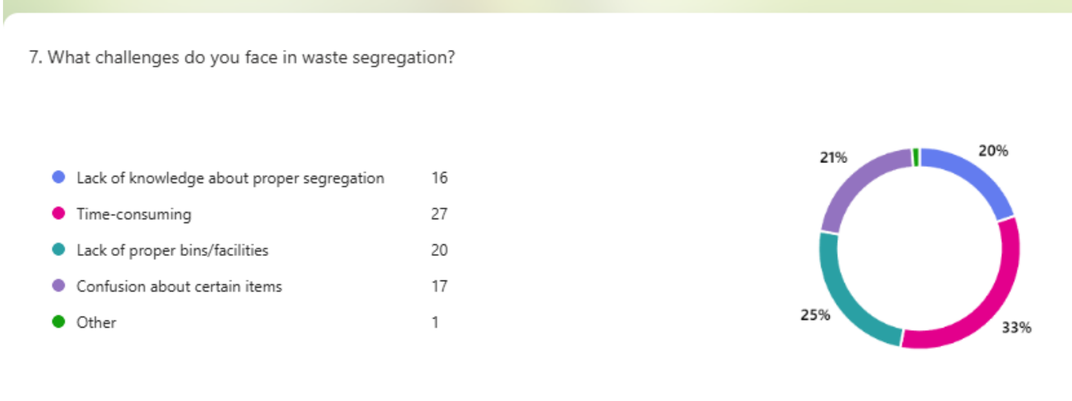

7. What challenges do you face in waste segregation?
Lack of knowledge about proper segregation 16
Time-consuming 27
Lack of proper bins/facilities 20
Confusion about certain items 17
Other 1
21%
20%
25%
33%

Figure 28: Pre-survey (Current waste management practices)

8. How comfortable are you with using smart devices?

9. Would you be willing to use a smart dustbin that automatically sorts waste?

10. What features would you find most useful in a smart waste management system? (Rank in order of importance)

Figure 29: Pre-survey (Technology adaption)

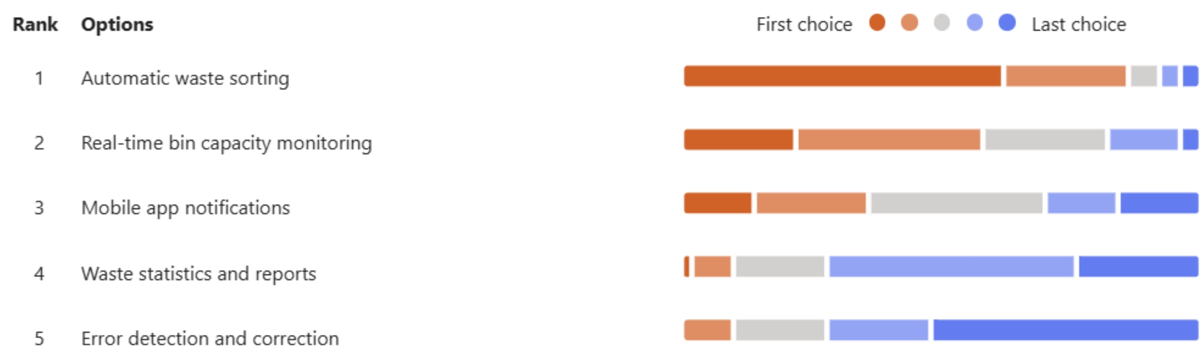


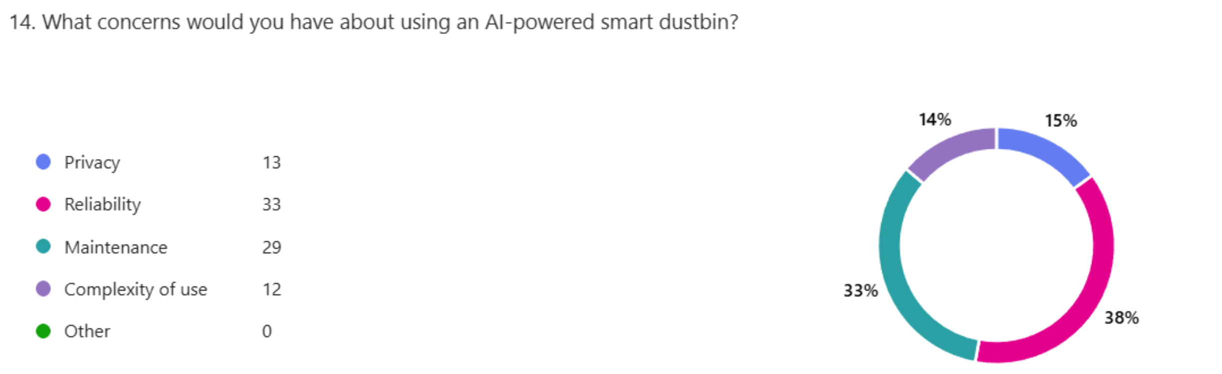
Figure 30: Ranking features in order of importance in a smart bin

11. How important is proper waste management to you?

12. Are you aware of the environmental impact of improper waste disposal?

13. Would you be willing to pay extra for a smart waste management solution?

Figure 31: Pre-survey (Environmental awareness)



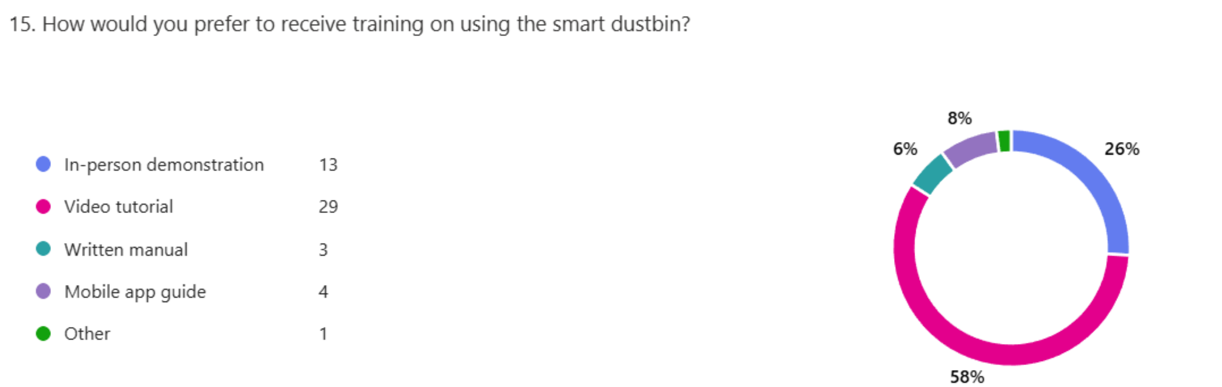


Figure 32: Pre-survey (Implementation concerns)

9.2. Literature Review

9.2.1. Introduction

In recent years, the problems of waste management have assumed strong trends in Nepalese environment, social, and economic sectors, requiring new approaches for solutions. Lack of infrastructure, population increase and increase in the rate of urbanization increase the problem of waste accumulation thereby posing a health and ecological risk. Hitherto methods of waste disposal which involve direct disposal in dumping sites are unsustainable hence the need for better solutions. Pursuing the aim of this essay to analyses outstanding innovative wastes management strategies having appeared in Nepal, the author of the essay is promising to shed the light on the efficiency of the that and their applicability for emulation. These solutions have the purpose of partnering Community Engagement, Technological Development and Sustainable Principles to minimize the short-term effects of waste contamination while advocating for circular economy. Finally, the analysis of these progressive approaches reveals the tension between the environmental agenda and developmental objectives in the Nepalese search for a successful solution for waste handling.

9.2.2. Overview of the waste management challenges in Nepal

The problems towards dealing with waste in the country remains rampant thus outlining the nature of the Nepal waste management system. With the advancement in urbanization and development especially within the densely populated cities of Nepal such as Kathmandu there is a significant increase in waste production over Council systems. These inefficiencies work hand in hand with inadequate facilities to ensure that a good proportion of waste, if not collected at all, ends up being deposited haphazardly, hence polluting water sources and the general environment. Moreover, the population has little knowledge of proper waste disposal and recycling methods or a proper attitude toward environmental problems. Most recently, the study done in Dhading Besi has brought into light the necessity of the inclusion of the environmental education in local curriculum to enhance the understanding of environment and encourage the community to participate in sustainable practices solely *(Bryce, 2014)*. This implies that Nepal's current waste management is not going to benefit from the emerging disciplinary strategies, which indicate that there is need for innovative solution for proper waste management.

9.2.3. Community-Based Waste Management Initiatives

Waste management programs based on communities in Nepal have become crucial approaches for dealing with the issues of waste disposal in the respective urban and rural areas. Such measures include participation of residents in methodical approach to waste management through involvement of local communities in formulation and implementation of plans. Such civil-society projects do not only increase the levels of waste sorting and recycling, but also establish pedagogy of proper environmentally responsible behaviour. That being the case, cross sectional studies reveal that community mobilization has led to higher levels of recycling and decreased landfill reliance and therefore made a positive impact to the environment *(Lidya Tesfaye, 2015)*. In addition, these interventions bring out the spirit of partnership especially between the sub-teams of local governments, non-governmental organizations and the community members as the share essential knowledge and resources required to manage wastes. Finally, the sustainability and success of such community-based approaches underpin the need of Nepal's larger strategy towards developing successful waste management solutions.

9.2.4. Role of local communities in promoting sustainable waste practices

Nepalese communities play the key roles of agents of change since they dominate most local settings hence directing sustainable waste management in those regions. By involving the people of a country in the task of managing and minimizing waste, not only is shared responsibility achieved, but locally appropriate and appropriate solutions are sought. Specific actions like the conduct of the WASTE segregation demonstrations and cleaners build up the capacity of an ordinary person to embrace the use of environmentally friendly practices. For instance, the involvement of communities through bottom-up approaches showed that understandings of bottom residents' situations could closely inform the core issues related to waste and potential ways of their solution. Further, involvement of the local governments is possible and may improve the efficiency of these practices since the local stakeholders always have deeper insight of the social and economic environments of their region *(Jacobsen, 2013)*. Thus, the grassroots level engagements of people in the selected communities of Nepal have social capital that can be tapped for enhanced waste innovation manage for a sustainable future of the environment *(Fliessbach, 2012)*.

9.2.5. Technological Innovations in Waste Processing

As commonly seen, adequate technology in waste processing of the available waste resources is central in formulating sustainable methods for waste management in Nepal. One such innovation includes the use of anaerobic digestion systems that in addition to decreasing organic waste transform it into biogas, which is a source of green energy within local communities. Furthermore, the work of automated sorting technologies makes the subsequent stages of recycling qualitatively better as it allows for the separation of materials as efficiently as possible. According to various authors, these innovations are especially useful in Nepal's urban areas given the increased population density that photo compounds the problem of waste management *(Karanjeet, 2013)*. It is imperative that all such technological solutions are implemented alongside main them with community engagement as implementation calls for public consciousness. Furthermore, ensuring that innovation is encourages within waste processing can help to increase the sustainability of Nepal's waste management (Drechsel et al., 2018).

9.2.6. Implementation of waste-to-energy technologies in urban areas

This paper aims to reveal the nature and imperative of waste management problems in the urban areas of Nepal and establish the potential of applying WtE technologies to reduce these problems and offer an energy supply. Anaerobic digestion where organic waste is converted into biogas or incineration of waste destined for non-recycling will enable cities to achieve two objectives: decreasing the amount of waste that is buried and generating renewable energy at the same time. Such a dual advantage leads to decreased release of greenhouse gases to the atmosphere and enhanced health statuses of the people. However, the integration of WtE technologies corresponds to the national strategic plans towards improving climate resilience, as explained in the literature concerning the development of local capacities for climate financing *(Lidya Tesfaye, 2015)*. Citizens and stakeholder involvement and multi-sectorial cooperation can foster commitments within regions hence enable urban areas to work on sustainable waste management. Finally, WtE implementation gives the solutions for the increasing waste problem in Nepal and at the same time promote energy security and responsibility.

9.3. SRS

9.3.1. Introduction

a. Purpose

The WasteWise project has addressed the system functionalities and non-functionalities in the Software Requirements Specification (SRS) document. This document defines the requirements of the Intelligent Waste Management System with IoT and AI incorporated. There is hardware and software related data in the document along with all other technological specifications.

b. Intended Audience

- Developer implementing the AI, IoT, and web components.
- Tester for system validation.
- Stakeholders interested in system capabilities.
- Future maintainers and developers.
- Project supervisors and evaluators.

c. Project Scope

WasteWise is an initiative to establish an organization that brings IoT devices together with AI technology besides designing an application that would help in the classification and monitoring of waste. Real time management of wastes generated, automated sorting of wastes, convenience in handling and monitor and analyse.

9.3.2. Overall Description

a. System Features

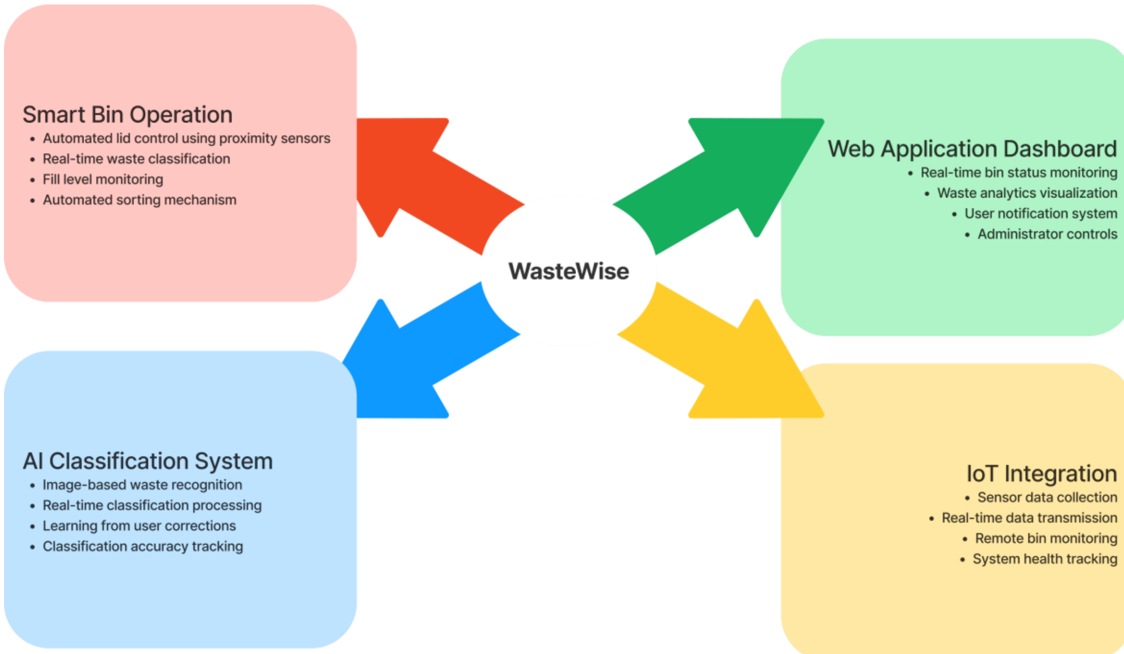


Figure 33: System Features

9.3.3. Functional Requirements

1. Smart Bin Operation

Table 5: Functional Requirement of Smart Bin Operation

Req. ID	**Requirement Description**	
FR.01	Smart bins must provide automated waste handling and classification.	
	Sys.Req.ID	**System Requirement**
	SR.01	System shall detect user presence and automatically open the lid
	SR.02	System shall capture images of disposed waste
	SR.03	System shall classify waste in real-time
	SR.04	System shall sort waste into appropriate compartments
	SR.05	System shall measure bin fill levels

2. AI Classification

Table 6: Functional Requirement of AI Classification

Req. ID	Requirement Description	
FR.01	System must accurately classify waste items.	
	Sys.Req.ID	**System Requirement**
	SR.06	System shall process waste images in real-time
	SR.07	System shall achieve 90% classification accuracy
	SR.08	System shall provide classification confidence scores
	SR.09	System shall allow manual correction of misclassifications
	SR.10	System shall learn from user corrections

3. Web Application

Table 7: Functional Requirement of Web Application

Req. ID	Requirement Description	
FR.01	System must provide web-based monitoring and control.	
	Sys.Req.ID	**System Requirement**
	SR.11	System shall display real-time bin status.
	SR.12	System shall generate waste analytics reports.
	SR.13	System shall send notifications for bin maintenance.
	SR.14	System shall provide administrative controls.
	SR.15	System shall track system performance metrics.

4. IoT Integration

Table 8: Functional Requirement of IoT Integration

<table>
<tr><th>Req. ID</th><th>Requirement Description</th></tr>
<tr><td>FR.01</td><td>System must enable real-time data collection and transmission.
<table>
<tr><th>Sys.Req.ID</th><th>System Requirement</th></tr>
<tr><td>SR.16</td><td>System shall collect sensor data continuously.</td></tr>
<tr><td>SR.17</td><td>System shall transmit data to central server.</td></tr>
<tr><td>SR.18</td><td>System shall monitor hardware health.</td></tr>
<tr><td>SR.19</td><td>System shall support remote configuration.</td></tr>
<tr><td>SR.20</td><td>System shall operate in offline mode when needed.</td></tr>
</table>
</td></tr>
</table>

9.3.4. Non-Functional Requirements

1. Performance

Table 9: Non-Functional Requirement of Performance

Req.ID	Requirement Description	Priority
PR.01	Classification response time < 2 seconds	Must
PR.02	Web application response time < 3 seconds	Must
PR.03	System uptime > 99%	Must
PR.04	Data transmission latency < 1 second	Should

2. Security

Table 10: Non-Functional Requirement of Security

Req.ID	Requirement Description	Priority
PR.01	Secure data transmission protocols	Must
PR.02	User authentication and authorization	Must
PR.03	Hardware safety mechanisms	Must
PR.04	Error handling and recovery	Must

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