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1. Introduction

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 (The Kathmandu 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.

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

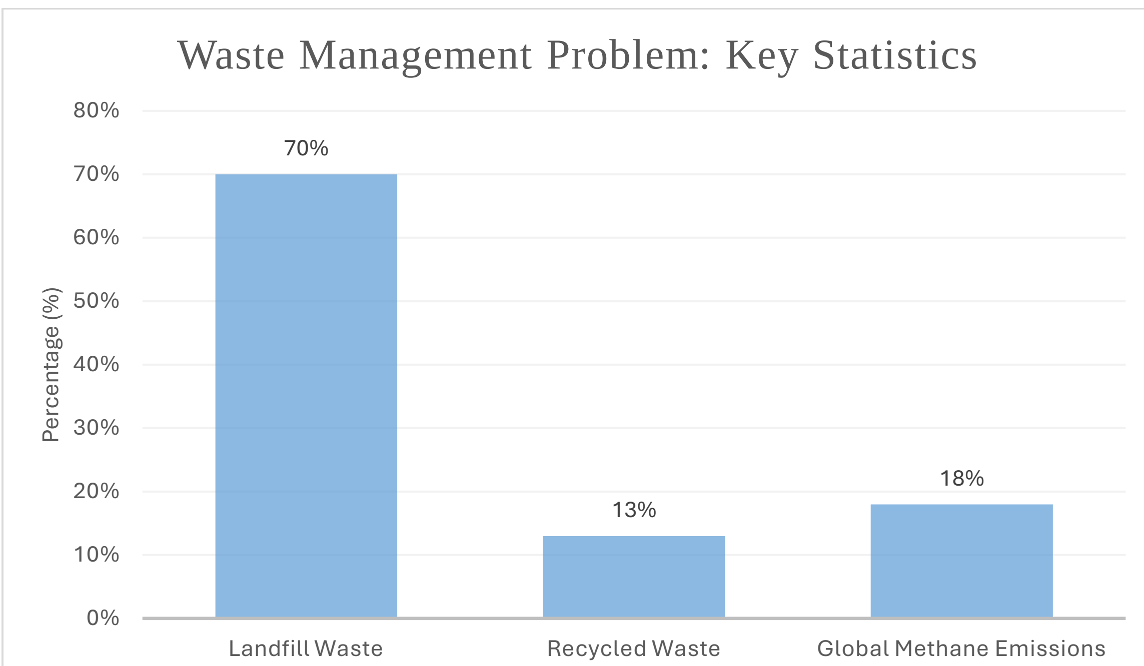
1.1. Problem Scenario

The problem that revolves around waste management is even worse, and based on estimates it is expected that landfill waste will actually increase by 70% by 2050 as is shown in What a Waste

2.0 report from the World Bank (The World 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 (European Commission, 2021). 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 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 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

2. Aim and Objectives

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.

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 sorting 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)

3. Expected Outcomes and Deliverables

3.1. Expected Outcomes

- The implementation of the AI-powered smart dustbin will lead to a significant increase in the accuracy of waste classification, ensuring that biodegradable and non-biodegradable materials are properly sorted.
- By providing a user-friendly web application, the project aims to engage users actively in waste management practices, leading to increased awareness and participation in recycling efforts.
- The integration of data analytics capabilities will result in valuable insights regarding waste generation patterns, enabling municipalities and households to optimize their waste management strategies.
- The project aims to contribute to sustainability by minimizing the amount of improperly disposed waste, thereby reducing landfill pollution and promoting recycling initiatives.
- Users will benefit from real-time updates on bin status and waste levels, facilitating timely actions for waste disposal and management.

3.2. Deliverables

- **AI-Powered Waste Classification System:** A fully functional system capable of detecting and categorizing waste into biodegradable and non-biodegradable types.
- **Smart Dustbin Prototype:** A physical prototype of the smart dustbin equipped with ultrasonic sensors for lid automation and AI capabilities for waste classification.
- **Web Application Interface:** A user-friendly web application that allows users to monitor bin status, receive notifications, and manage the smart dustbin remotely.
- **Error Detection Mechanism:** A feature that identifies misclassified waste and provides options for manual correction, ensuring accurate waste segregation.
- **Data Analytics Reports:** Regular reports generated by the system detailing types and quantities of waste collected, as well as usage statistics for insights into waste management practices.

- **Final Project Report:** A comprehensive report summarizing the project development process, outcomes achieved, challenges faced, and recommendations for future improvements in waste management systems.

4. Project Risks, Threats and Contingency Plans

Table 1: Risk Matrix for WasteWise

	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Almost Certain (5)	User interface navigation errors	Minor data input errors			
Likely (4)		Basic maintenance needs	Integration issues	Sensor malfunction	
Possible (3)		Incorrect waste sorting	System downtime	Data security breach	Environmental compliance violation
Unlikely (2)			Training gaps		Complete system failure
Rare (1)				Natural disaster impact	Critical infrastructure failure

Risk Level Indicators:

Extreme Risk
High Risk
Medium Risk
Low Risk

5. Methodology

5.1. 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 keeps 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

5.2. Selected Methodology: Evolutionary Prototyping

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

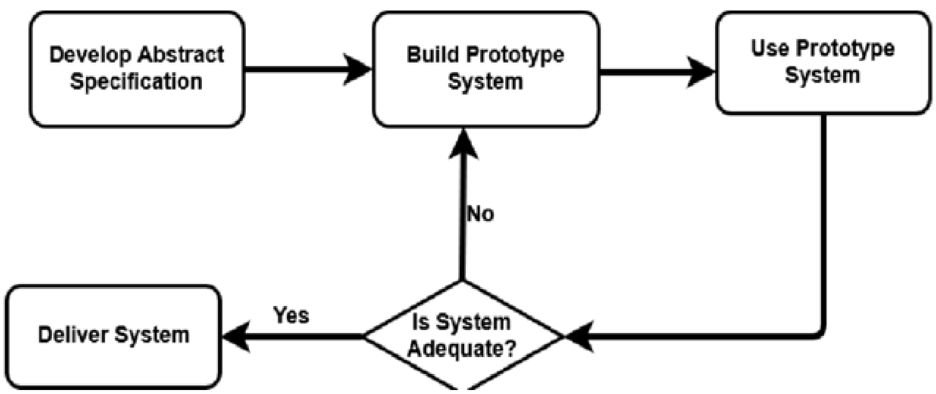


Figure 2: Evolutionary Prototype

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 mockups
- 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 feature and capabilities growth

4. Testing Phase:

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

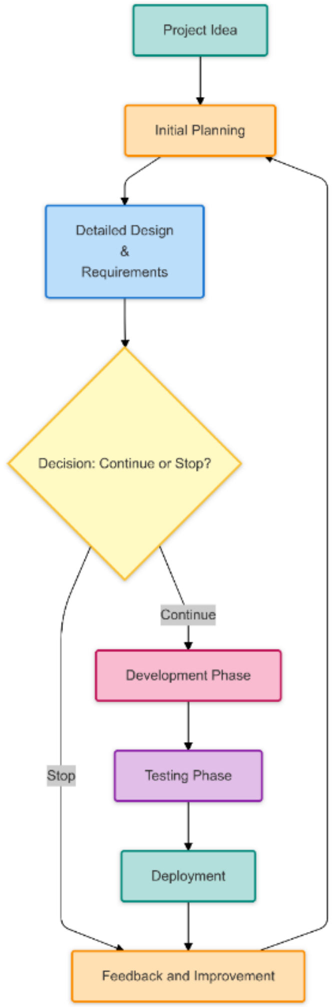


Figure 3: WasteWise SDLC flowchart

6. Resource Requirements

6.1. 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

6.2. 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 preprocessing.
- Django: Framework for building backend services.
- React: Framework for building frontend services.

7. Work Breakdown Structure

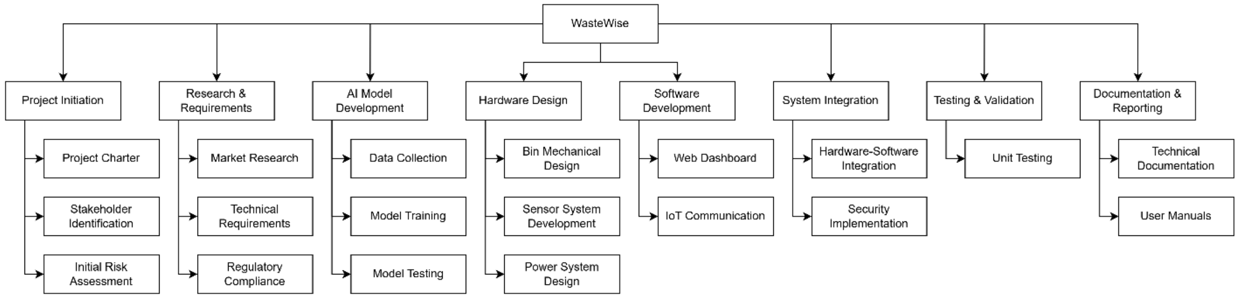


Figure 4: Work Breakdown Structure

8. Milestones

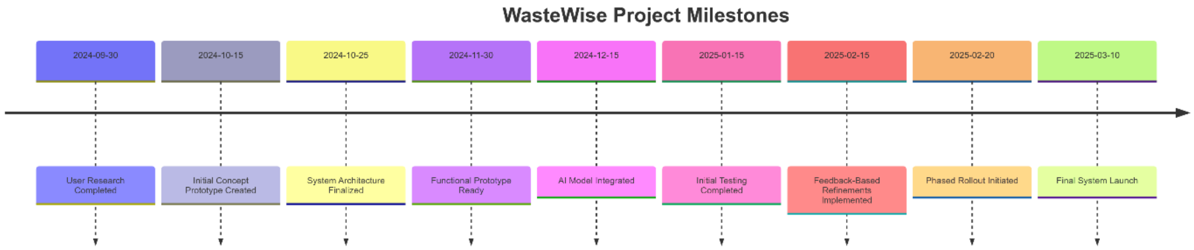


Figure 5: Milestones of the project

9. Project Gantt Chart

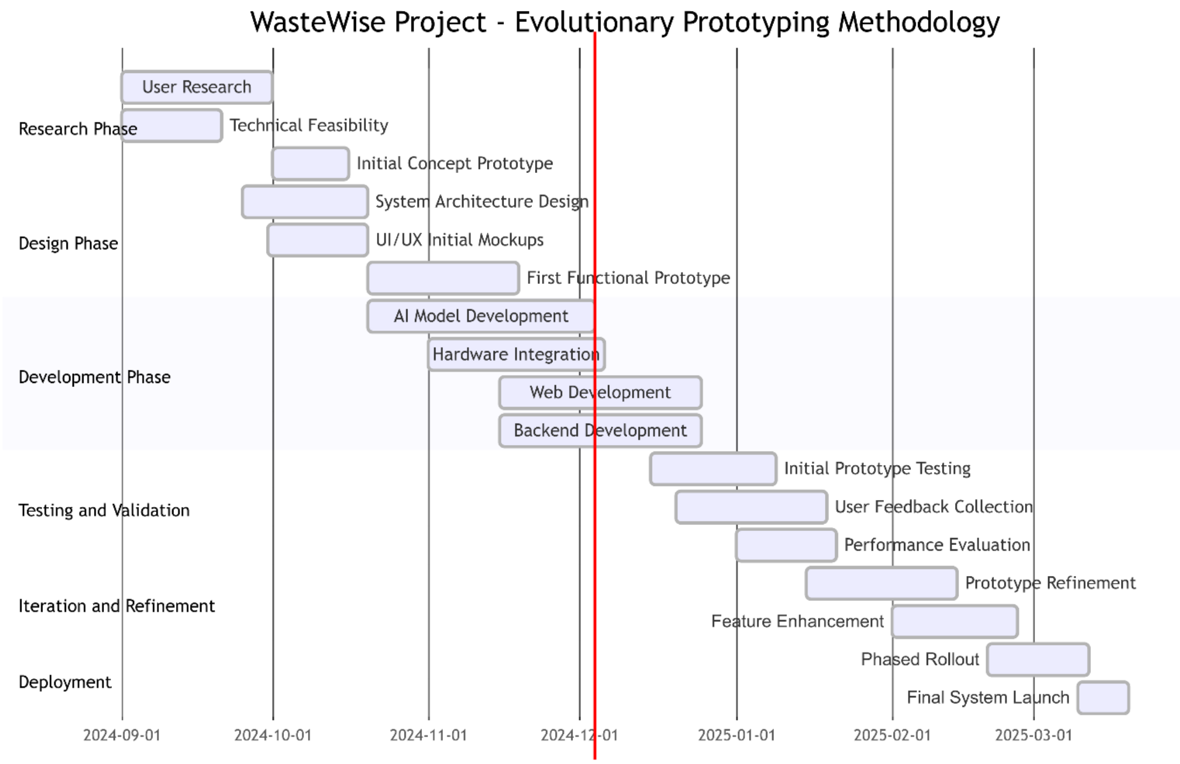


Figure 6: Gantt Chart

9.1. Detailed Timeline Tables

Research Phase

Table 2: Detailed Research Phase Timeline

Task Name	Task ID	Start Date	Duration	Dependencies	Deliverable
User Research	a1	2024-09-01	30 days	None	Insights on user needs and expectations
Technical Feasibility	a2	2024-09-01	20 days	None	Feasibility report on technical solutions
Initial Concept Prototype	a3	After a1	15 days	a1	A basic conceptual prototype for initial review

Design Phase

Table 3: Detailed Design Phase Timeline

Task Name	Task ID	Start Date	Duration	Dependencies	Deliverable
System Architecture Design	b1	2024-09-25	25 days	None	Initial system blueprint
UI/UX Initial Mockups	b2	2024-09-30	20 days	None	Wireframes and mockups of key screens
First Functional Prototype	b3	After b1, b2	30 days	b1, b2	Functional prototype integrating design and architecture

Development Phase

Table 4: Detailed Development Phase Timeline

Task Name	Task ID	Start Date	Duration	Dependencies	Deliverable
AI Model Development	C1	2024-10-20	45 days	None	Initial AI model for waste classification
Hardware Integration	C2	2024-11-01	30 days	None	Integration of sensors and actuators with control logic
Web Development	C3	2024-11-15	40 days	None	Interactive front-end web application
Backend Development	C4	2024-11-15	40 days	None	Fully functional backend for data processing and storage

Testing and Validation

Table 5: Detailed Testing Phase Timeline

Task Name	Task ID	Start Date	Duration	Dependencies	Deliverable
Initial Prototype Testing	d1	2024-12-15	25 days	c1, c2, c3, c4	Test results documenting system reliability
User Feedback Collection	d2	2024-12-20	30 days	d1	User feedback report for prototype improvement
Performance Evaluation	d3	2025-01-01	20 days	d1, d2	Performance benchmark data

Iteration and Refinement

Table 6: Detailed Iteration Phase Timeline

Task Name	Task ID	Start Date	Duration	Dependencies	Deliverable
Prototype Refinement	e1	2025-01-15	30 days	D3	Refined prototype with enhancements
Feature Enhancement	e2	2025-02-01	25 days	d1	Enhanced system with improved features and usability

Deployment

Table 7: Detailed Deployment Phase Timeline

Task Name	Task ID	Start Date	Duration	Dependencies	Deliverable

Phased Rollout	f1	2025-02-20	20 days	e2	Initial deployment with phased implementation
Final System Launch	f2	2025-03-30	10 days	f1	Fully deployed and operational WasteWise system

10. Conclusion

WasteWise project allows proposing a new approach to the modern challenges of waste management and creates an AI IoT and design-centered experience. WasteWise also increases recycling effectiveness besides improving the indicators of contamination through automation of waste recognition, differentiation, and separation. The systematized approach of the project starts with research, followed by prototyping, testing, and deployment guarantees both effective performance and real-world utility. Additionally, the use of real-time performance and data analysis enables stakeholders to enhance the efficiency of waste collection and disposal adequately. Through WasteWise it becomes clear how technological advancements can be used to help achieve the goal of reducing waste, environmental degradation and promoting better waste management practices among various communities.

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