WASRUK

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### BACHELOR OF TECHNOLOGY IN

**COMPUTER SCIENCE**

****

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# CERTIFICATE

This is to certify that Project Report entitled “ WASRUK ” which is submitted by Satyendra Singh, Sneha, Satyam Srivastava in partial fulfillment of the requirement for the award of degree B. Tech. in Department of Computer Science of Dr. A.P.J. Abdul Kalam Technical University, Lucknow is a record of the candidates own work carried out by them under my supervision. The matter embodied in this report is original and has not been submitted for the award of any other degree.

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Last but not the least, we acknowledge our friends for their contribution in the completion of the project.

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# ABSTRACT

India faces a mounting waste crisis, generating over 65 million tonnes annually with minimal recycling, resulting in expanding landfills and environmental degradation. WASRUK addresses this challenge through an innovative digital platform that rewards proper waste segregation with WCoins, vouchers, and cashback, creating tangible incentives for sustainable behavior.The system combines mobile applications with local waste collection services, employing gamification techniques to enhance user engagement. Blockchain technology ensures transparency and security in tracking waste segregation activities and reward transactions, building trust within the ecosystem.Developed using Agile methodology, WASRUK creates a scalable, user-friendly platform designed to be accessible across diverse regions and demographic groups throughout India. Comprehensive testing—including unit, integration, and user acceptance testing—ensures system reliability and performance. Pilot testing demonstrates increased participation in segregation practices and heightened awareness of proper disposal methods. The platform delivers dual benefits: economic advantages through reduced municipal waste management costs and new employment opportunities, alongside environmental improvements including decreased landfill usage and natural resource conservation.As a technological solution grounded in behavioral economics, WASRUK offers a promising approach to India's waste management challenges, incentivizing sustainable practices at the grassroots level while fostering a circular economy. By connecting waste generators with proper disposal channels through an engaging reward system, WASRUK represents an innovative step toward addressing one of India's most pressing environmental challenges.

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**LIST OF ABBREVIATION**

API- Application Programming Interface AWS- Amazon Web Services

CAGR- Compound Annual Growth Rate CSS- Cascading Style Sheet

CSR- Corporate Social Responsibility DBMS- Database Management System DFD- Data Flow Diagram

ER- Entity Relationship GPS- Global Positioning System

HTML- Hyper Text Markup Language HTTP- Hyper Text Transfer Protocol IOT- Internet Of Things

JSON- Javascript Object Notation KPI- Key Performance Indicator

MSW- Muncipal Solid Waste

MVC- Model View Controller NGO- Non-Governmental Organisation

NoSQL- Not Only SQL

REST- Represntational State Transfer RFID- Radio Frequency Identification SDLC- Software Development Life Cycle SDK- Software Development Kit

SRS- Software Resource Specification SSL- Secure Sockets Layer

UI- User Interface

UML- Unified Modeling Language UX- User Experience

WCRA- World Coalition for Recycling And Awareness

# SDG MAPPING WITH JUSTIFICATION

The WASRUK project aligns with several of the United Nations Sustainable Development Goals (SDGs), demonstrating its commitment to global sustainability efforts:

### SDG 11: Sustainable Cities and Communities

WASRUK directly contributes to making cities inclusive, safe, resilient, and sustainable by improving urban waste management infrastructure and practices. By encouraging waste segregation at the source, the project helps reduce the environmental footprint of urban areas, decreases pollution, and promotes resource efficiency in cities.

### SDG 12: Responsible Consumption and Production

The core objective of WASRUK is to promote sustainable consumption patterns through proper waste management. By incentivizing waste segregation, the project encourages responsible disposal practices, facilitates recycling, and contributes to the circular economy. This aligns perfectly with the targets of SDG 12 related to reducing waste generation and promoting sustainable management of natural resources.

### SDG 13: Climate Action

Improper waste disposal, particularly in landfills, contributes significantly to greenhouse gas emissions. By diverting waste from landfills through better segregation and recycling, WASRUK helps mitigate climate change by reducing methane emissions from decomposing organic waste, thereby contributing to SDG 13's goals of combating climate change and its impacts.

### SDG 8: Decent Work and Economic Growth

WASRUK creates economic opportunities in the waste management and recycling sectors, potentially generating new jobs and income streams. The rewards system also provides economic benefits to participants, contributing to inclusive economic growth as outlined in SDG 8.

### SDG 17: Partnerships for the Goals

The implementation of WASRUK requires collaboration between multiple stakeholders, including local governments, waste collectors, community members, and technology providers. This multi-stakeholder approach exemplifies the partnership model advocated by SDG 17 to achieve sustainable development goals.

The WASRUK project's comprehensive approach to waste management demonstrates how technological innovation can be leveraged to address multiple sustainability challenges simultaneously, making it a valuable contribution to the global sustainable development agenda.

# CHAPTER 1:

**INTRODUCTION**

## Introduction to Project

India is at a vitally important turning point in its waste management process, it is confronted with unprecedented challenges for which there has to be innovative and sustainable solutions. With its burgeoning population currently over 1.4 billion and vast urbanization altering the face of the land, the country produces more than 65 million tonnes of waste each year with an outlook to substantially increase in the next decades. This waste includes but is not limited to municipal solid waste, agricultural residues, hospital waste, industrial by products and the increasing tide of electronic waste plying the precise course for waste management authorities everywhere.

The effects of poor waste management are extensive and quite serious. Environmental degradation includes forms of soil and water contamination i.e. toxic substances from waste not disposed of properly in the environment filters to the ecosystem. Public health is facing increasing risks with disease vectors incubating in accumulated waste and pollutants that are airborne during unregulated waste burning. This unchecked spread of landfills not only encroaches valuable land territory, but also generates methane (a powerful greenhouse gas), thereby making substantial contribution towards climate change .

The traditional approaches to the management of the waste flow based on landfill and incineration have been found to be woefully inadequate to manage the magnitude and complexity of the modern waste stream. Exist in highly advanced technological form; industrialized waste to energy plants and automated sorting facilities, yet their effectiveness is intrinsically bound to effective source segregation of waste, a practice which has not been uniformly adopted in India’s varied urban and rural compositions .

This gap between what waste management technology can offer and what can be achieved through community participation is a severe choke point in India’s journey to sustainable waste management. Technological development is not capable of solving this crisis; Waste management needs a behavioral change not only at the individual level but also at the community level. Here the WASRUK Project makes its intervention with its innovative approach.

WASRUK – an abbreviation of “Waste and Rukawat” or obstacle in Hindi, intends to de- obstruct members of waste management chain by providing incentive for the segregation at household level. The project introduces an all encompassing digital platform which turns waste segregation from being a civic obligation to an entertaining and rewarding business venture. By utilizing WASRUK mobile application and web platform, the users can obtain data on their waste segregation activities, accrue virtual rewards in the form of WCoins and exchange those for physical awards including gift vouchers, cashback and discounts from eco-friendly products.

WASRUK uses behavioral economics principles by establishing a direct association between responsible waste management and personal benefits to meet the environmentally friendly practices. The platform’s gamification components such as leader boards, badges, family rank mechanisms provide a healthy competition and community participation which strengthens positive waste management practices even more. Proper awareness and motivation; understanding of correct techniques of waste handling accompanied by persuasive incentives is recognized as necessary for such reforms.

The WASRUK system architecture is integrated effortlessly with the current waste collection infrastructure through a special interface for the waste collectors. This integration allows for real-time verification of the compliance with waste segregation, thus maintaining the integrity of the reward system, but offering beneficial data concerning generation patterns of waste. Blockchain technology where waste segregation activities and (reward) transaction are recorded, adds another layer of transparency and security thus creating trust between all the parties involved in the waste management ecosystem.

The economic and environmental consequences of broad deployment of the WASRUK platform are significant. Correct waste segregation at the point of generation decreases the operating costs of waste processing facilities; it increases the recovery of useful recyclables and reduces the number of landfills used and the carbon footprint associated with waste management. For societies, the platform provides an economic venue in the form of reward system and possibilities for development of local recycling initiatives.

As India works to solve its waste management problems in accordance with national priorities and international commitments such as Sustainable Development Goals, innovative approaches like WASRUK are indicative of a bright future, one in which community participation is seen as central to successful sustainable waste management systems. Insights into the conceptualization, design, adoption and testing of the WASRUK platform are reported in this project report assessing the prospect of changing the waste management process in India.

## Project Category

The WASRUK project represents an overlap of several technical categories due to its multidisciplinary character in confronting the intricate issue of waste management.

### Mobile and Web Application Development

At its center, WASRUK is a web platform with mobile applications for Android and iOS systems, with a complementary web front-end. The touchpoints of these applications are the key interactions users have with the incentive system for waste segregation.

### Internet of Things (IoT) Integration

IoT elements are integrated into the project through the use of mobile devices employed by waste collectors to confirm waste segregation at the household level. This principle establishes a system of interconnected devices which enable real-time collection and verification of data in a field situation.

### Blockchain Technology

WASRUK uses blockchain technology to keep a secure, transparent and cannot be altered record of waste segregation activities and reward transactions. This is going to provide integrity of the incentive system and add to the trust of all stakeholders.

### Data Analytics and Machine Learning

The platform utilizes data analytics to analyze waste segregation patterns, thus they are able to optimize collection routes, predict patterns of waste generation and personalize incentives provided to people based on their behavior analysis.

### Gamification and Behavioral Economics

Gamification principles are administered by WASRUK in the way of leaderboard, achievement badges, and family ranking system that uses rules of behavioral economics to encourage sustainable waste management activities.

### Environmental Technology

As a stranded environmental technology solution WASRUK tackles the critical problem of waste management through the practice of waste segregation at the source, recycling and minimization of the waste disposal environmental impact.

### Sustainable Development

The project is in line with several SDGs and therefore fits into the larger class of technological interventions aimed at contributing to the realization of sustainable development and combating global environmental challenges. This multidimensional categorization points to the complexity of the waste management problem and the whole pack of solutions offered by the WASRUK project to resolve it. Integrating different technological domains, WASRUK is a comprehensive solution that addresses both a technical and behavioral issue with sustainable waste management.

## Objectives

The WASRUK project has been developed based on a well defined agenda of objectives, which guide implementation and also guide the evaluation process. These goals include technological; behavioral; environmental; and economic dimensions as can be pointed at the multifaceted nature of waste management problem.

### Primary Objectives:

#### To grow a scalable digital platform to reward the segregation of waste at household level.

 To grow a scalable digital platform to reward the segregation of waste at household level.

* Develop an intuitive mobile application and online interface for monitoring waste segregation activities.

* + - * Create a secure reward system using the technology of blockchain.
      * Promote an appealing user experience that is relevant to different demography.

#### For enhancing the rate of proper segregation of waste in involved communities.

 Have at least a 40% improvement in waste segregation compliance within six months of actual implementation.

* Promote sustainability of behavioral change through sustained interaction.

 Increase user base to 100,000 households in the first period, that involves a pilot phase.

#### In order to minimize the adverse effect on the environment due to unproper disposal of waste.

* + - * Reduce the amount of mixed waste sent to landfills by not less than 30%.

 Raise recycling recovery rate of recyclable materials from 35%.

* Mitigate greenhouse-gas emissions caused by waste decay in landfills.

##### In order to create economic value with better waste management practices.

* Facilitate the savings in costs for municipal waste management authorities.

* Generate avenues to gain income from the WASRUK reward system.

 Develop local industries of recycling.

### Secondary Objectives:

#### In order to gather useful data on the pattern of waste generation.

* Create understanding on the composition of household waste in different regions.

 Determine seasonal variations in waste production.

* Develop prognostic models for waste management planning.

##### In order to educate the public in an environmental manner.

* Enhance education on what effective waste management entails within the platform Initiate forums where the environment become a major topic of discussion (environmental sustainability).

 Create a culture of environmental responsibility.

#### To develop a model of collaborative management of waste.

* Engage a range of stakeholders such as households, waste collectors, and local authorities.

* Applied to demonstrate public private partnerships through waste management.

* Develop a framework that can be replicated in multiple contexts.

1. **For supporting policy development of sustainable waste management. *** Insights based on evidence for the formulation of waste management policy. * Prove the effectiveness of incentive-based approaches of waste segregation  Support the implementation of Solid Waste Management Rules 2016 [3].

Such objectives are consistent with the overarching endpoints of sustainable development; SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The attainment of these objectives at a successful rate would go a long way in in solving India’s challenge in the waste management, as it will bring up environmental, social, and economic benefits to the communities involved.

## a. Structure of Report

This detailed project report on the WASRUK platform consists of eight chapters that discuss various aspects of the conceptions, developments, implementations, and evaluations of the project:

#### Chapter 1: Introduction

Gives an overview of the challenges of waste management in India, introduces the WASRUK concept, defines the project category, and specifies the goals underlying the development, the implementation of the project.

#### Chapter 2: Literature Review

Discusses current research and projects related to waste management with emphasis on digital platforms, models of incentivization, and community engagement strategies. This chapter describes important research gaps that the WASRUK project addresses and formulates the particular problem statement that underpins the project.

#### Chapter 3: Proposed System

Provides the reader with a complete description of the system architecture WASRUK, its main components, technical features, and workflow of this system. This chapter emphasizes the distinctive elements of the WASRUK approach that distinguishes it from current waste management options.

#### Chapter 4: Requirement Analysis and System Specification

Performs an all-encompassing feasibility study with respect to technical, economic and operational aspect. It outlines the software requirements specification on data, functional, performance, maintainability, and security requirement. The chapter gives an account of the SDLC model used in development as well as the system design in the form of the data flow diagrams, use case diagrams and database design.

#### Chapter 5: Implementation

Describes the process of implementing tools and technologies that were used to create the WASRUK platform. This chapter offers the practical picture of turning WASRUK concept into reality, touching the coding practices, integration aspects, and deployment aspects.

#### Chapter 6: Testing and Maintenance

Describes the testing approaches used for testing of reliability, security and performance of the WASRUK platform. It provides test scenarios for various system components, details the maintenance approaches that are used to maintain continued operation and progression of the platform.

#### Chapter 7: Results and Discussions

Shows the results of the implementation of the WASRUK project including the detailed descriptions of system modules and screenshots, major results of the pilot implementation epoch, and analysis of the database structure with illustrative snapshots. This chapter presents evidence that supports functionality and effectiveness of the platform.

#### Chapter 8: Conclusion and Future Scope

Summarizes the main accomplishments and insights from the WASRUK project, assesses the impact of the WASRUK project on the management of India’s waste, and discusses pointers for future development and exposition of the WASRUK platform.

The report ends with a complete list of references based on the IEEE format, a Turnitin result document, the paper acceptance certificate, copy of the published paper, and proof of publication of patent where applicable.

This systematic arrangement guarantees documentation of all the WASRUK project components to serve as a valuable platform for understanding the conception, design, implementation, and possible effects of the innovative legacy project.

# CHAPTER 2: LITERATURE REVIEW

* 1. **Literature Review**

The waste management field has undergone significant development worldwide while noting the need to adopt new approaches to combat mounting waste problem. This literature review explores the available literature and research projects on the topic of waste management, with special emphasis on digital platforms, incentivization schemes and community engagement strategies that shape the way the WASRUK project is planned.

### The Global Waste Management Challenge

In its “What a Waste 2.0” report, World Bank forecasts that by 2050, the amount of waste produced globally will rise by 70 percent to amount to 3.40 billion tonnes per annum [1]. This trend is most acute in less developed countries such as India where rapid urbanization, increased population and altered consumption patterns conspire to push waste volumes up. According to the report, proper waste management continues to pose a significant global problem with compelling environmental, social and economic consequences. According to UN Environment Programme’s Global Waste Management Outlook, poor waste management contributes to 5- 10% of global greenhouse gas emissions, mainly from methane production during the decomposition of organic waste in landfills [2]. The report advocates for the paradigm shift from the conventional methods of disposal of waste (dumping in landfills) to rather sustainable future waste management systems which emphasize waste prevention, reuse, and recycling.

### India's Waste Management Context

India’s waste management is full of unique prospects and dilemmas. Simplifying its challenge, Jha and Singh (2020), examine the intricacies of the waste management process in India, acknowledging while banal regulatory schemes have been introduced as a measure in place including in the form of the Solid Waste Management Rules 2016, it continues to be inconsistently implemented across the nation zones [5]. The authors report a number of barriers to effective waste management such as poor infrastructure and finances, poor public awareness and ineffective waste collection systems. Kumar and Saini (2019) investigate waste management technologies in India and find that, although technological solutions do exist, current effectiveness is limited by lack of systematic waste segregation at source [6]. This is an important deficiency in the waste management chain that cannot be bridged by technology alone but demands individual and community change in behavior. The Centre for Science and Environment’s report on “India’s Waste Crisis” seeks decentralized practices of waste management and propagates the use of circular economy principles [7]. The report highlights the potential of community-based approaches and importance of developing economic incentives that would ensure sustainable waste management possibilities.

### Digital Platforms in Waste Management

The utilization of digital technologies in the processes of waste management is a promising way to resolve present problems. The National Institute of Urban Affairs study on “Waste management in Indian cities” recognizes technology adoption as a major enabler of effective municipal waste management that would be helpful in optimizing collection routes, monitoring waste generation patterns and enhancing community participation [8]. Pradhan and Das (2021) explore the use of technology in India’s waste management system and report the ability of mobile applications to meet the gap between waste generators and waste processors [15]. Their research implies that platforms with digital interfaces may be useful proxies for information exchange, publicity, and promotion of sustainable practices in regard to waste.

### Incentivization Models for Behavioral Change

Behavioral change is acknowledged as an important component for waste management issues. Gundimeda and Sethi (2018) examine the environmental as well as economic benefits of recycling in India designating economic incentives as powerful drivers for achieving waste segregation and recycling behaviors [14]. Their research indicates that elegantly designed incentive systems can drastically boost participation in practice of sustainable waste management. Some of the international examples like RecycleBank in the United States indicate the success of reward-based strategies for recycling. Based on the above, the platform offers users points for segregating recyclables that later on, they can redeem for discounts and services by way of gamification encouraging for the participation on the part of the users. [4].

### Blockchain Technology in Environmental Applications

New research examines the application of blockchain technology to environmental applications, waste management among them. The qualities that characterize the blockchain, that is transparency, immutability, and decentralization are those which particularly make the blockchain a pragmatic tool for tracking flows of waste, verifying the conformity of those with procedures attached to waste management, and for enabling credible transaction on incentives systems.

### Similar Projects and Initiatives

Numerous initiatives have used both digital platforms and incentive schemes on waste recycling practices:

#### Smart Waste Management System (Jain University, India)

This program uses GPS powered smart bins and real time tracking to improve the effectiveness of waste picking. It comprises a user application for reporting waste and an administrative panel for tracking collection activities.

#### RecycleBank (United States)

Users of RecycleBank are rewarded with points for classification of recyclables, which can be exchanged for benefits and services. Gamification is utilised by this platform to promote recycling behaviors and has proved its ability to raise recycling rates in involved communities.

#### Kabadiwala (India)

The platform connects the households and business people with the recyclers for post consumer waste collection and recycling. It aims at promoting segregation of waste off take rather than segregation at source.

#### EcoEx (India)

EcoEx helps recycling plastic waste through plastic credit trade by uniting plastics generators, recyclers and producers. Propriety in waste management is shown to have economic promise through this market approach.

### Gamification in Environmental Behavior Change

Findings of studies about the topic of gamification in environmental contexts show that aspects of the game like points, badges, leaderboards and challenges can succeed at motivating pro- environmental behaviors. Studies indicate that gamification can help improve engagement and maintain participation towards community competition on environmental initiatives, such as the waste management programs.

### Waste Segregation's Effect on the Economy and Environment.

Mishra and Soni (2020) examine recycling and waste management prospects in India in light of the circular economy [12]. Their study highlights the potential for resource recovery, job creation, and waste processing cost savings while quantifying the economic value of appropriate waste segregation. From an environmental point of view, Sharma and Kumar (2021) report that efficient waste segregation and recycling procedures have reduced greenhouse gas emissions, reduced contamination of soil and water, and conserved natural resources [10].

## Research Deficits

The literature review highlights a number of important shortcomings in current waste management strategies, especially when it comes to India:

### Limited Combination of Behavioral Economics and Technology

The literature on waste management has examined behavioral interventions and technological solutions independently, but little is known about integrated strategies that use behavioral economics concepts in conjunction with digital platforms to promote sustainable waste management practices. When it comes to solving waste segregation issues, the potential synergy between technology and behavioral science is still mostly unrealized.

### Insufficient Attention to Source Segregation

Although the significance of waste segregation at the source is acknowledged, the majority of digital waste management platforms prioritize waste collection optimization over providing incentives for appropriate segregation. This is a lost chance to address the waste management chain's crucial initial step.

### Absence of All-Inclusive Incentive Models

Simple reward mechanisms are frequently used in waste management incentive systems that do not take into account the complexity of human motivation. Creating all-encompassing incentive models that combine social recognition, community involvement, and various reward types to promote long-lasting behavioral change is lacking.

### Inadequate Techniques for Community Engagement

Effective community engagement tactics in the context of digital waste management platforms have not received much attention, despite the fact that community participation is recognized as crucial for successful waste management. There is still much to learn about how gamification, social comparison, and community competition can promote group action.

### Waste Management Does Not Use Blockchain Integration

Blockchain is still in its infancy as an integration technology for waste management systems, despite its potential to improve transparency and trust in environmental applications. There is a lack of knowledge about how blockchain technology can be used to enable safe reward transactions and confirm waste segregation compliance.

* + 1. **Limited Evaluation of Economic and Environmental Impacts** Blockchain is still in its infancy as an integration technology for waste management systems, despite its potential to improve transparency and trust in environmental applications. There is

a lack of knowledge about how blockchain technology can be used to enable safe reward

transactions and confirm waste segregation compliance..

### Limited Assessment of Environmental and Economic Effects.

The economic and environmental effects of digital platforms for waste management in India are not well supported by empirical data. To prove the value of innovative waste management techniques, thorough evaluations that measure cost savings, resource recovery, greenhouse gas reduction, and other advantages are required.

## Problem Formulation

The WASRUK project tackles the following major issues in light of the thorough literature review and the research gaps that were found:

### The main issue

Inadequate waste segregation at the source exacerbates India's waste management crisis, leading to economic inefficiencies, environmental degradation, and public health hazards. In order to encourage sustainable waste segregation practices at the household level, current solutions fall short in combining behavioral incentives with technological innovation.

### Particular Issues Resolved

#### Inadequate Source-Level Waste Segregation

Effective recycling and appropriate waste processing are hampered by the uneven implementation of waste segregation at the source throughout India, despite legal mandates.

* + - 1. **Limited Encouragement to Adopt Sustainable Waste Management Practices** Without offering concrete incentives that can encourage long-lasting behavioral change, current strategies for encouraging waste segregation mainly rely on environmental

awareness or regulatory compliance..

#### Disjointed Ecosystem for Waste Management

Overall system efficiency is decreased by the waste management chain's frequent siloed operations and poor coordination between waste generators, collectors, processors, and regulatory bodies.

#### Inadequate Information on Waste Generation Trends

Evidence-based planning and the development of waste management policies are hampered by the absence of systematic data collection on the generation and segregation patterns of household waste.

#### Digital Technologies Are Underutilized

Current waste management systems do not fully utilize the potential of digital platforms, blockchain, and gamification to improve waste management practices.

#### Waste's Economic Potential Is Unrealized

Existing waste management models do not adequately account for the economic potential of appropriate waste segregation, including resource recovery and the creation of green jobs.

### Research Questions

The WASRUK project seeks to address the following research questions:

1. How can digital platforms effectively incentivize waste segregation at the household level in the Indian context?
2. What combination of rewards and gamification elements most effectively drives sustained participation in waste segregation activities?
3. How can blockchain technology enhance transparency and trust in waste management incentive systems?
4. What are the quantifiable economic and environmental benefits of improved waste segregation at source?
5. How can a digital waste management platform be designed to be scalable and adaptable across diverse urban and rural contexts in India?

The WASRUK project seeks to address these issues and research questions in order to create a comprehensive solution that connects technological innovation and waste management behavior change, thereby promoting more environmentally friendly waste management practices throughout India.

# CHAPTER 3: SUGGESTED SYSTEM

* 1. **The Suggested Framework**

The WASRUK system is a cutting-edge method of waste management that encourages waste segregation at the source by combining behavioral economics, digital technology, and community involvement. The main elements, architecture, and features of the suggested system are described in this section.

#### System Overview

WASRUK is a comprehensive digital platform designed to incentivize proper waste segregation at the household level through a reward-based system. The platform consists of interconnected components that facilitate user engagement, waste tracking, reward distribution, and data analytics, creating a cohesive ecosystem for sustainable waste management.

The core of the WASRUK system is a mobile application and complementary web platform that enables users to:

* + - * Track and report their waste segregation activities
      * Earn digital rewards (WCoins) for proper waste segregation
      * Redeem rewards for tangible benefits such as gift vouchers, cashback, and discounts
      * Participate in community challenges and competitions.
      * Get instructional materials about proper waste management techniques.

Through a special interface for waste collectors, who use mobile devices to confirm waste segregation compliance, the platform integrates with nearby waste collection services. In addition to offering useful information on waste generation trends, this verification procedure guarantees the integrity of the reward system.

### System Architecture

The WASRUK system architecture, which consists of multiple interconnected layers supporting the platform's functionality, is made to be secure, scalable, and resilient:

#### Frontend Layer

* Mobile Application (Android and iOS)  Web Interface

 Waste Collector Mobile Interface  Administrative Dashboard

#### Backend Layer

 Application Server (Node.js)

 Database Management System (MongoDB)  Authentication and Authorization Services  Reward Management System

 Blockchain Integration

#### Integration Layer

 APIs for third-party services integration  Payment Gateway Integration  Notification Services  Analytics Engine

Infrastructure Layer

 Cloud Hosting (AWS)

 Content Delivery Network  Data Storage and Backup  Security Infrastructure

With separate services managing particular functions like user management, waste tracking, reward distribution, and data analytics, the system is designed using a microservices

architecture. This method improves maintainability and scalability by enabling independent scaling or updating of individual components.

### Key Components

#### System for User Management

Permissions, profile management, authentication, and user registration are all managed by the user management system. It keeps thorough user profiles with metrics for community involvement, reward transactions, waste segregation history, and demographic data.

#### System for Tracking Waste

Through the mobile application, users can record their waste segregation activities thanks to this component. It has tools for scheduling waste collection, documenting the kinds and amounts of waste that are separated, and taking pictures to provide visual proof. Every user's waste segregation history is kept up to date by the system.

#### System of Verification

The verification system uses a two-step verification procedure to guarantee the accuracy of waste segregation reporting:

1. Visual confirmation using user-uploaded photos.
2. During collection, waste collectors physically verify.

Mobile devices that enable them to verify the correct segregation of waste at the time of collection are provided to waste collectors. The process of calculating and allocating rewards is initiated by this verification.

#### System for Reward Management

Based on confirmed waste segregation efforts, the reward management system computes and allots WCoins. It uses a dynamic reward algorithm that takes into account variables like:

* + The amount and kinds of waste that are separated
  + Segregation's consistency over time
  + Taking part in community challenges
  + Finishing the instructional modules

Additionally, the system oversees the redemption of WCoins for a range of rewards, such as cashback, gift cards, and partner company discounts.

#### Ledger for Blockchain

A safe, transparent, and unchangeable record of waste segregation operations and reward transactions is offered by the blockchain component. The blockchain records every verified waste segregation activity and reward distribution as a transaction, protecting the reward system's integrity and fostering user trust.

#### Platform for Community Engagement

This component facilitates community interaction and healthy competition through:

* + A leaderboard showing the best waste segregation performers.
  + Family and neighborhood ranking systems
  + Community challenges and competitions
  + Forums for exchanging advice and experiences
  + Acknowledgment tools like achievements and badges

#### System for Managing Educational Content

Interactive information on sustainability, environmental impact, and waste management techniques is provided by the educational component. It consists of:

* + Instructions on appropriate waste segregation methods

* Details regarding the advantages of recycling for the environment  Local waste management policy updates

* Challenges and tests to strengthen learning

#### Engine for Analytics

In order to produce insights regarding waste segregation patterns, user engagement, and environmental impact, the analytics engine analyzes data from multiple system components. Impact analysis, reward strategy improvement, and system optimization are all influenced by these insights.

#### Dashboard for Administration

For system administrators, the administrative dashboard offers extensive management features such as:

* Monitoring and management of users  Management of partner businesses

* Configuration of the reward system  Management of content

* Monitoring of system performance  Reporting on impact assessments

### Workflow for Operations

The workflow used by the WASRUK system is as follows:

#### Onboarding and User Registration

* Users can access the web platform or download the WASRUK mobile application.

* They set up accounts with their social media credentials, phone number, or email address.

 Users fill out their profiles with location and household information.

* An interactive tutorial on waste segregation procedures and platform usage is offered by the system.

#### Waste Segregation and Reporting

 Users separate household waste into specific categories, such as organic waste and recyclables.

 Using the mobile application, they record the segregation activity, including the kinds and amounts of waste.

 As visual proof, users take pictures of the waste that has been separated.

 The action is noted by the system in the user's waste segregation history.

#### Collection and Verification of Waste

 Through the platform, users can schedule waste collection.

 Collection requests are sent to local waste collectors via their mobile interface.

 Waste collectors use their mobile devices to ensure that waste is properly separated during collection.

 The platform updates the verification status in real time.

#### Distribution and Calculation of Rewards

* Based on confirmed waste segregation efforts, the system determines rewards.

 The user's account is credited with WCoins.

* The blockchain ledger contains a record of the transaction.

 Notifications about earned rewards are sent to users.

#### Redemption of Rewards

* Through the platform, users peruse the available redemption options.

 They choose the incentives they want (cashback, gift cards, etc.).

 The redemption request is processed by the system.

 The chosen reward is given after WCoins are taken out of the user's account.

#### Participation in the Community

 Users take part in competitions and challenges within the community.

 Top waste segregation performers are shown on the leaderboard.

* When users participate consistently, they receive badges and achievements.

 Discussions and knowledge sharing are facilitated by community forums.

#### Reporting and Data Analytics

 Data on waste segregation patterns is continuously gathered and analyzed by the system.

 Information about system performance, environmental impact, and user engagement is produced.

 Information about system performance, environmental impact, and user engagement is produced.

#### Optimization of the System

* The system improves user engagement mechanisms and reward schemes based on analytics insights.

* Updates are made to educational materials to fill in identified knowledge gaps.

 The purpose of community challenges is to focus on particular waste management goals.

### Technological Framework

Several state-of-the-art technologies are used by the WASRUK system to provide its functionality:

#### Development of Mobile Applications

 For cross-platform compatibility (iOS and Android), use React Native.

* Native modules for features unique to a given device (camera, GPS, notifications)

 The web interface's Progressive Web App (PWA) features

#### Backend Development

* Node.js for implementing APIs and server-side logic  Developing RESTful APIs with Express.js

* Scalable NoSQL database administration with MongoDB  Redis for session management and caching

#### Blockchain Implementation

* Private blockchain implementation using Hyperledger Fabric  Smart contract-based automated reward distribution

 Digital wallets for WCoin management

#### Infrastructure Based on the Cloud

* Cloud hosting that is scalable using Amazon Web Services (AWS)  Amazon S3 for storing data and images

 Amazon S3 for image and data storage

 Using AWS Lambda for serverless computing tasks and Amazon CloudFront for content delivery

#### Implementation of Security

 OAuth 2.0 for authentication and authorization

* JWT (JSON Web Tokens) for safe information sharing  Encrypting sensitive data from beginning to end

 Secure communication using HTTPS

#### Analytics and Machine Learning

* TensorFlow for predictive analytics
* Amazon SageMaker for deploying machine learning models
* Custom algorithms for reward optimization and user behavior analysis
  1. **Unique Features of The System**

The WASRUK system incorporates several distinctive features that differentiate it from existing waste management solutions and address the specific challenges identified in the problem formulation:

### Comprehensive Incentivization Model

In contrast to conventional waste management strategies based on civic duty or compliance, WASRUK uses a multi-level incentivization model that blends:

#### Economic Incentives

 WCoins exchangeable for material rewards * Local business partnership for discount deals  Cashback on utility payments and services

#### Social Incentives

 Leaderboard-based community recognition * Consistent participation achievement badges  Family and neighborhood ranking systems ***Intrinsic Motivators***

 Environmental impact visualization

 Progress tracking towards sustainability goals

 Educational content that strengthens the importance of correct waste handling

This multifaceted solution addresses different motivational drivers that govern behavior, promot ing the chances of long-term involvement in waste segregation activities.

### Blockchain-Based Verification and Reward System

WASRUK uses blockchain technology to generate an open, secure, and unalterable record of waste segregation activities and reward transactions. This aspect:

 Guarantees the integrity of the verification process

* Prevents manipulation and fraud within the reward system

* Builds trust among users, waste collectors, and partner companies  Ensures an open audit trail for all transactions

* Allows secure and efficient distribution of rewards

Implementation of the blockchain also enables the future possible integration of WASRUK with other carbon credit schemes and sustainability projects..

### Two-Step Verification Process

The system applies a distinct two-step verification process to segregation of wastes:

### Digital Verification:

The users present photographic proof of correct segregation of the wastes using the mobile app.

### Physical Verification:

Proper segregation is confirmed by waste collectors upon collection through their mobile phones.

This two-way verification mechanism guarantees correctness in waste segregation reporting and protects the integrity of the reward scheme. It further provides a feedback loop that reinforces the right waste segregation procedure through direct verification and reward.

### A Family-Centered Approach

Given that managing waste is frequently a domestic task, WASRUK takes a family-centered approach that:

* Permits several family members to make contributions to a single household account. * Applies challenges and rewards at the family level.

* Encourages healthy competition between families in the same neighborhood  Makes it easier for generations to share waste management knowledge.

This method extends the impact beyond individual users to entire households by utilizing family dynamics to promote sustainable waste practices..

### Integration with the Infrastructure for Local Waste Collection

WASRUK integrates with the current local waste collection services rather than setting up a separate waste collection system by:

* An app specifically designed for waste collectors

* Coordination in real time between collectors and users  Digital monitoring of collection routes and timetables  Metrics of performance for waste collection services

By adding a digital layer that facilitates tracking, reward distribution, and verification, this integration improves the effectiveness of the current waste collection infrastructure.

### System of Adaptive Learning

An adaptive learning system built into the WASRUK platform does the following: * Examines user behavior trends to pinpoint areas in need of development.

* Adapts instructional materials to user knowledge gaps. * Modifies incentive schemes to maximize participation

* Aadjusts objectives and challenges according to user performance.

For users with different levels of environmental awareness and waste management expertise, this adaptive approach guarantees that the system will continue to be useful and interesting.

### Gamification Based on the Community

WASRUK incorporates community-based gamification components in addition to individual gamification:

* Neighborhood issues that call for cooperation

 Community achievements that grant access to more benefits

 Competitions between residential areas that are cooperative

* Community platforms for exchanging information and resolving issues

By encouraging group efforts and social reinforcement, this community-centered strategy cultivates an atmosphere that is conducive to sustainable waste management techniques.

### Visualization of Real-Time Environmental Impact

The platform lets users see how their waste segregation efforts affect the environment in real time:

* Preventing the measurement of greenhouse gas emissions * Calculation of the amount of landfill space saved

* Calculation of the resources saved by recycling  Cumulative community impact visualization

By linking individual behaviors to observable environmental results, this feature maintains user motivation and emphasizes the importance of appropriate waste segregation.

### Platform for Multi-Stakeholder Collaboration

WASRUK acts as a platform for collaboration between various waste management ecosystem stakeholders, including:

* Families (sources of waste) * Local garbage haulers

* Local government officials  Facilities for recycling

* Corporate partners (for sponsorships and incentives)

In order to improve waste management techniques, this multi-stakeholder approach fosters coordination and generates synergies.

### Support for Data-Driven Policies

The system produces useful information and insights that can guide the creation of waste management policies:

* Detailed regional patterns of waste generation

* Finding the obstacles to efficient waste segregation

 Evaluation of the efficacy of incentives for various demographic groups

 Assessment of the financial and environmental effects of better waste management

This data-driven strategy aids in the development of evidence-based policies and the distribution of resources for waste management projects.

All of these special qualities work together to solve the main issues raised in the problem formulation, resulting in a complete solution that goes beyond conventional waste management techniques to promote long-lasting behavioral change at the individual, family, and community levels.

# CHAPTER 4: REQUIREMENTANALYSIS AND SYSTEM

**SPECIFICATION**

* 1. **Project Viability (Feasibility Study)**

A thorough study confirmed WASRUK's potential across technical, economic, and operational aspects.

### Technical Feasibility

Existing smartphone usage, affordable collector devices, scalable cloud infrastructure, and sufficient network coverage make the technology viable. React Native for apps, Node.js/MongoDB for backend, and identified blockchain expertise support development. Scalability, compatibility, offline access, and security are addressed in the design. Conclusion: Technically achievable with current tech and expertise.

### Economic Feasibility

Development costs are estimated at ₹15L for software, ₹5L for hardware, ₹2L for infrastructure setup plus ₹30k per month, and ₹8L for blockchain. Operational costs are projected at ₹30-50k per month for infrastructure, ₹10L per year for support, ₹20L per year for rewards, and ₹20L per year for personnel. Revenue streams include municipal partnerships, corporate sponsorships,partner commissions, data insights, and grants. ROI analysis indicates sustainability within three years, along with broader economic and environmental benefits. In conclusion, it is economically viable, presenting diverse revenue opportunities and significant indirect benefits.

### Operational Feasibility

Positive user reception and a strong incentive model support adoption. Integration with existing waste systems and policy alignment are feasible. Training, verification management, reward sustainability, and phased rollout address operational challenges. A dedicated team and support infrastructure are planned. Conclusion: Operationally viable with strategies to address challenges and encourage participation.

#### Conclusion on Operational Feasibility

The operational feasibility assessment concluded that the WASRUK project is operationally viable, with clear strategies for addressing potential challenges. The alignment with existing waste management infrastructure and policy objectives enhances the project's operational feasibility, while the comprehensive approach to user engagement supports adoption and participation.

### 4.1.1 Overall Feasibility Conclusion

WASRUK is feasible with proper investment and implementation. Key success factors include stakeholder engagement, user-friendly design, sustainable rewards, robust verification, and scalable tech. The project offers a promising approach to India's waste management.

## Software Requirement Specification

### Data Requirement

The WASRUK system requires comprehensive data management to support its various functions. The data requirements encompass user information, waste segregation records, reward transactions, and system configuration data.

#### User Data

 **Personal Information**: Name, contact information (email, phone number), residential address, family size

 **Authentication Data**: Login credentials, security questions, authentication history

 **Profile Information**: User preferences, notification settings, profile picture

 **Household Information**: Number of family members, dwelling type, geographical location

 **User Activity Data**: Login history, feature usage patterns, interaction with educational content

#### Waste Segregation Data

 **Segregation Records**: Date, time, types of waste segregated, quantities (estimated weight or volume)

 **Verification Data**: Photos of segregated waste, verification status, verification timestamp

 **Collection Records**: Collection requests, scheduled collection dates, collection confirmation

 **Historical Segregation Data**: Segregation patterns over time, waste composition trends

#### Reward System Data

 **WCoin Balance**: Current balance, lifetime earnings, expiry information

 **Transaction History**: WCoin earning events, redemption transactions, transaction timestamps

 **Reward Catalog**: Available redemption options, WCoin requirements, partner businesses

 **Redemption Records**: Redemption requests, processing status, delivery information

***Community Engagement Data***

 **Leaderboard Data**: User rankings, performance metrics, historical ranking positions

 **Challenge Data**: Active challenges, participation records, challenge completion status

 **Achievement Records**: Badges earned, progress toward achievements, achievement timestamps

 **Community Metrics**: Neighborhood participation rates, collective impact metrics

#### Waste Collector Data

* **Collector Profiles**: Name, contact information, assigned areas, performance metrics

* **Collection Routes**: Scheduled collections, route optimization data, collection history

* **Verification Records**: Verification activities, accuracy metrics, verification timestamps

 **Equipment Data**: Mobile device information, maintenance records, usage statistics

#### System Configuration Data

* **Reward Parameters**: Reward calculation rules, WCoin values for different activities

* **Geographical Data**: Area definitions, neighborhood boundaries, collection zones

 **Partner Information**: Business details, discount offerings, partnership terms

 **Educational Content**: Articles, videos, tutorials, quizzes, content metadata

#### Analytics Data

 **User Behavior Metrics**: Engagement patterns, feature usage statistics, retention metrics

 **Waste Management Metrics**: Segregation rates, recycling volumes, waste composition analysis

 **Environmental Impact Metrics**: Greenhouse gas reduction, landfill diversion, resource conservation

 **System Performance Data**: Response times, error rates, system availability metrics

#### Data Storage and Retention Requirements

 User data to be stored for the duration of account activity plus 12 months

* Segregation and verification data to be retained for a minimum of 5 years for analysis

 Transaction data to be maintained for 7 years for audit purposes

 Anonymized analytics data to be preserved indefinitely for long-term trend analysis

#### Data Privacy and Security Requirements

 Personal data to be encrypted at rest and in transit

* User consent required for data collection and processing

 Data access controls based on role-based permissions

 Regular data backups with secure off-site storage

 Data anonymization for analytics and reporting purposes

### Functional Requirement

The functional requirements define the specific capabilities and features that the WASRUK system must provide to users, waste collectors, administrators, and other stakeholders.

#### User Management Functions

##### User Registration and Authentication

* + - * + The system shall allow users to register using email, phone number, or social media accounts

 The system shall implement secure authentication mechanisms, including multi-factor authentication

* The system shall support password recovery and account management functions

* The system shall maintain user profiles with customizable preferences and settings

#### Household Management

 The system shall enable the creation of household accounts with multiple associated users * The system shall allow users to specify household characteristics relevant to waste generation  The system shall aggregate waste segregation activities at the household level

 The system shall support household-level challenges and rewards

#### Waste Segregation Functions

##### Waste Segregation Tracking

 The system shall provide an interface for users to log waste segregation activities

* The system shall support categorization of waste into predefined types (recyclables, organic, etc.)

 The system shall allow users to record estimated quantities of segregated waste

 The system shall maintain a historical record of segregation activities for each user

#### Waste Collection Coordination

* The system shall enable users to schedule waste collection through the platform

 The system shall notify appropriate waste collectors about collection requests

 The system shall provide status updates on scheduled collections

 The system shall allow users to provide feedback on collection services

#### Verification System

 The system shall support photo-based verification of segregated waste

* The system shall provide waste collectors with a mobile interface for physical verification

* The system shall record verification outcomes and trigger appropriate reward calculations

 The system shall flag inconsistencies or potential fraud for administrative review

#### Reward System Functions

##### WCoin Management

* The system shall calculate and distribute WCoins based on verified waste segregation activities

 The system shall maintain accurate WCoin balances for all users

 The system shall record all WCoin transactions on the blockchain ledger

 The system shall provide users with transaction history and balance information

#### Reward Redemption

 The system shall present users with available redemption options

* The system shall process redemption requests and deduct appropriate WCoin amounts

 The system shall coordinate with partner businesses for reward fulfillment  The system shall track redemption status and notify users of progress

#### Partner Business Integration

 The system shall maintain a catalog of partner businesses and their offerings

* The system shall facilitate the integration of new partners and their reward options

 The system shall track redemption activities with each partner

 The system shall provide partners with relevant analytics on redemption patterns

#### Community Engagement Functions

##### Leaderboard and Ranking System

* The system shall calculate and display user rankings based on waste segregation performance

 The system shall implement family and neighborhood ranking systems * The system shall update rankings in real-time as new

activities are verified

 The system shall maintain historical ranking data for trend analysis

#### Challenge and Achievement System

* The system shall create and manage various challenges related to waste segregation

 The system shall track user progress toward challenge completion * The system shall award badges and achievements based on predefined criteria

 The system shall notify users of new challenges and achievement milestones

#### Community Interaction

 The system shall provide forums for users to share experiences and tips

* The system shall facilitate neighborhood-level coordination for waste management initiatives

 The system shall support community events and collective challenges  The system shall enable knowledge sharing and peer learning

#### Educational Functions

##### Content Delivery

 The system shall provide educational content about waste management practices

* The system shall present content in various formats (text, images, videos, interactive modules)

 The system shall recommend relevant content based on user behavior and knowledge gaps

 The system shall track content consumption and comprehension

#### Knowledge Assessment

* The system shall include quizzes and assessments to evaluate user knowledge

 The system shall provide feedback on assessment performance * The system shall adapt educational content based on assessment outcomes

 The system shall recognize and reward knowledge acquisition

#### Administrative Functions

##### User Management

* The system shall provide administrators with tools to manage user accounts

 The system shall support user support functions, including issue resolution

* The system shall implement user access controls and permission management

 The system shall monitor user activity for security and compliance purposes

#### System Configuration

 The system shall allow administrators to configure reward parameters

* The system shall support the management of geographical data and collection zones

 The system shall enable the configuration of verification rules and processes

 The system shall provide tools for managing educational content and challenges

#### Reporting and Analytics

 The system shall generate comprehensive reports on system performance

* The system shall provide analytics on waste segregation patterns and trends

 The system shall track environmental impact metrics and economic benefits

 The system shall support data export for external analysis and reporting

#### Waste Collector Functions

* + - 1. **Collection Management**

* The system shall provide waste collectors with information on scheduled collections

 The system shall optimize collection routes based on request locations  The system shall track collection activities and completion status

 The system shall facilitate communication between collectors and users

#### Verification Tools

* The system shall equip waste collectors with tools for verifying waste segregation

 The system shall record verification outcomes and supporting evidence

 The system shall calculate collector performance metrics

 The system shall provide collectors with feedback on verification accuracy

### Performance Requirements

The Wasruk platform must meet the following performance requirements to ensure efficient operation and user satisfaction:

#### Response Time

* Mobile app screens should load within 2 seconds under normal network conditions

 API responses should be delivered within 3 seconds

 Reward calculations and WCoin crediting should be processed within 5 seconds after verification

#### System Availability

 The system should maintain 99.5% uptime during operational hours

 Scheduled maintenance windows should be limited to low-usage periods (typically between 2:00 AM and 4:00 AM)

 Automatic failover mechanisms should be implemented to minimize service disruptions

#### Scalability

 The system should support a minimum of 10,000 concurrent users initially

 Architecture should allow horizontal scaling to accommodate up to 1 million users without significant redesign

 Database performance should not degrade when handling large volumes of waste segregation data

#### Resource Utilization

 Mobile application should consume less than 100MB of device storage

* Battery consumption should be optimized to ensure minimal impact on user devices

 Server resources should be dynamically allocated based on usage patterns

#### Throughput

 The system should handle at least 100 waste segregation transactions per second

 Bulk processing capabilities for reward distribution should process 10,000 rewards per hour

 Data synchronization between mobile devices and central servers should occur within 30 seconds

#### Latency

* Blockchain verification should complete within 10 seconds  User authentication should complete within 3 seconds

* Leaderboard updates should be processed and displayed within 5 minutes of new data entry

### Maintainability Requirements

To ensure long-term viability and ease of updates, the Wasruk system must adhere to these maintainability requirements:

#### Modularity

 The system architecture must follow modular design principles

* Components should be loosely coupled to allow independent updates and modifications

 Microservices architecture should be implemented where appropriate to isolate functions

#### Documentation

 Complete API documentation must be maintained

 Code should include comprehensive comments following standard conventions

 System architecture and database schemas should be documented and kept updated

#### Version Control

 All source code must be managed through Git repositories

 Proper branching strategies should be implemented (Git Flow)

 Regular code reviews must be conducted before merging changes

#### Testing Framework

* Automated unit tests should cover at least 80% of all code  Integration tests should validate all critical system interfaces

 Regression testing procedures must be established for updates

#### Upgrade Path

* The system should support seamless version upgrades without service interruption

 Database migrations should be automated and reversible

 Mobile apps should support backward compatibility for at least two previous versions

#### Monitoring and Diagnostics

* Comprehensive logging should be implemented across all system components  Performance metrics should be continuously collected and available for analysis

 Alerting mechanisms should notify administrators of potential issues before they impact users

### Security Requirements

The Wasruk platform must implement robust security measures to protect user data and system integrity:

#### User Authentication and Authorization

 Multi-factor authentication for user accounts

* Role-based access control (RBAC) for system functions

 Session management with automatic timeout after 30 minutes of inactivity

 Secure password policies (minimum 8 characters, combination of uppercase, lowercase, numbers, and special characters)

#### Data Protection

 All user data must be encrypted at rest and in transit

* Personal information should be stored using industry-standard encryption (AES-256)

 Blockchain technology should be used for immutable transaction records  Data retention policies must comply with relevant regulations

#### API Security

 All APIs must be authenticated using OAuth 2.0 or JWT * Rate limiting to prevent abuse and denial of service attacks

* Input validation and sanitization to prevent injection attacks  Regular security testing of API endpoints

#### Mobile Application Security

* Certificate pinning to prevent man-in-the-middle attacks  Local data encryption on user devices

* Secure biometric authentication integration where supported  Prevention of runtime manipulation and reverse engineering

#### Compliance

 Adherence to GDPR principles for European users * Compliance with India's Personal Data Protection Bill  Regular privacy impact assessments

 Transparent data collection and usage policies

### Security Operations

* Regular vulnerability scanning and penetration testing  Incident response plan and procedures

* Security patch management with timely updates

 Audit logging of all security-relevant events

### SDLC Model Used

The Wasruk project has adopted the Agile development methodology, specifically Scrum, as its primary Software Development Life Cycle (SDLC) model. This choice was made to accommodate the evolving nature of waste management solutions and the need for frequent iteration based on user feedback.

#### Rationale for Selecting Agile/Scrum

##### Iterative Development

* The complexity of waste management requires an iterative approach to refine features  Enables continuous improvement based on real-world usage patterns

 Allows for rapid adaptation to changing user requirements

##### Stakeholder Engagement

* Regular sprint reviews facilitate direct feedback from waste collectors and users  Product backlog prioritization ensures focus on high-value features

 Daily stand-up meetings enhance communication within the development team

##### Risk Management

 Early and continuous delivery reduces project risks

* Frequent testing cycles identify issues before they become critical  Sprint retrospectives allow for process improvements

#### Implementation of Agile Methodology

##### Sprint Structure

* Two-week sprint cycles for development iterations  Sprint planning at the beginning of each cycle

 Daily stand-up meetings for progress tracking

 Sprint review and retrospective at the end of each cycle

##### User Stories and Backlog Management

* User stories created for all features with acceptance criteria  Backlog grooming sessions held weekly

 Story point estimation for effort assessment

 Continuous backlog prioritization based on business value

##### Continuous Integration/Continuous Deployment (CI/CD)

 Automated build and test processes

 Deployment to staging environment after each sprint

* Production deployments following user acceptance testing  Automated regression testing for quality assurance

### System Design

#### Data Flow Diagrams

The data flow within the Wasruk system is illustrated through the following diagrams, representing how information moves between different components and entities:

#### Level 0 DFD (Context Diagram)

The context diagram shows the Wasruk system as a single process interacting with external entities:

 Users (Households) * Waste Collectors

 Reward Partners

 Municipal Authorities Data flows include:

 Waste segregation data from Users to Wasruk

* Verification data from Waste Collectors to Wasruk  Reward information from Wasruk to Users

* Aggregated statistics from Wasruk to Municipal Authorities  Partnership data between Reward Partners and Wasruk **Level 1 DFD**

The Level 1 DFD breaks down the Wasruk system into its major processes:

* + - 1. User Registration and Authentication
      2. Waste Segregation Tracking
      3. Verification System
      4. Reward Calculation and Distribution
      5. Reporting and Analytics
      6. Leaderboard Management

These processes interact with four main data stores:

 User Profiles

* Waste Segregation Records  Reward Transactions

* System Configuration Key data flows include:

 User credentials flowing from Registration to Authentication * Segregation data moving from Tracking to Verification

 Verified records flowing to Reward Calculation

* Performance metrics feeding into Leaderboard Management

#### Level 2 DFD: Waste Segregation Tracking

This detailed diagram focuses on the waste segregation tracking process:

1. Waste Category Selection
2. Photo Evidence Capture
3. Location Tagging
4. Timestamp Recording
5. Data Validation
6. Storage in Blockchain

Data flows include validation checks, error handling, and confirmation messages to users.

#### Use Case Diagrams

The Use Case Diagrams illustrate the interactions between actors and the Wasruk system:

##### Primary Actors

* Household Users  Waste Collectors

* System Administrators * Municipal Authorities  Reward Partners

##### Key Use Cases for Household Users

* + - 1. Register Account
      2. Login to System
      3. Record Waste Segregation
      4. Upload Evidence
      5. View Reward Balance
      6. Redeem Rewards
      7. Check Leaderboard Position
      8. Access Educational Content
      9. Report Issues

##### Key Use Cases for Waste Collectors

1. Login to Collection App
2. View Collection Schedule
3. Verify Waste Segregation
4. Upload Verification Evidence
5. Complete Collection Record
6. Report Issues

##### Key Use Cases for System Administrators

1. Manage User Accounts
2. Configure Reward Parameters
3. Review System Analytics
4. Manage Partnerships
5. Handle Dispute Resolution
6. System Maintenance

##### Key Use Cases for Municipal Authorities

1. Access Aggregated Data
2. Generate Reports
3. View Waste Management Metrics
4. Configure Regional Parameters

##### Key Use Cases for Reward Partners

1. Manage Reward Offerings
2. View Redemption Statistics
3. Process Reward Claims

### Database Design

The Wasruk system utilizes a hybrid database approach, combining relational and NoSQL structures to handle different data requirements efficiently. This design supports the complex relationships between entities while maintaining high performance for real-time operations.

#### Entity-Relationship Diagram (ERD)

The core entities in the Wasruk database and their relationships are as follows:

##### Primary Entities:

* Users (Households)  Waste Collections

* Verification Records  Rewards

 Transactions

* Waste Categories  Collectors

* Reward Partners

### Key Relationships:

* Users generate multiple Waste Collections * Collectors verify multiple Waste Collections  Users receive multiple Rewards

* Rewards are provided by Reward Partners  Users perform multiple Transactions

* Waste Collections are categorized into Waste Categories

#### Data Indexing Strategy

To ensure optimal query performance, the following indexing strategy is implemented:

### Relational Database Indexes:

* + - 1. B-tree indexes on all primary keys
      2. Hash indexes on frequently searched fields (email, username)
      3. Composite indexes for common query patterns, such as:

 (user\_id, collection\_date) on waste\_collections  (category\_id, status) on waste\_collections

 (user\_id, transaction\_type) on transactions

### NoSQL Database Indexes:

1. TTL (Time-To-Live) indexes on log data for automatic expiration
2. Compound indexes on frequently queried combinations:

 (user\_id, activity\_type, timestamp) on user\_activities

 (leaderboard\_type, calculation\_date) on leaderboard

1. Text indexes on search fields in analytics collection

#### Data Migration and Backup Strategy

##### Data Migration Plan:

* + - 1. Initial data import from existing waste management systems
      2. Transformation of legacy data to match the new schema
      3. Validation process to ensure data integrity after migration
      4. Phased migration approach by geographical regions

##### Backup Strategy:

1. Daily incremental backups of all databases
2. Weekly full backups stored across multiple geographic locations
3. Point-in-time recovery capability with transaction log backups every 30 minutes
4. Monthly backup restoration tests to verify recovery procedures
5. Encrypted backups with restricted access controls

#### Database Performance Optimization

To maintain high performance as the system scales:

##### Query Optimization:

* Prepared statements for all database operations  Stored procedures for complex operations

 Query plan analysis and optimization

##### Caching Strategy:

 Redis cache for frequently accessed data

* Application-level caching for user profiles and leaderboards  Time-based cache invalidation policies

##### Sharding Strategy:

* Horizontal partitioning of collection data by geographic region  User data sharding based on user ID ranges

 Time-based sharding for historical transaction data

# CHAPTER 5: IMPLEMENTATION

### Introduction: Tools and Technologies Used

The implementation of the Wasruk system leverages a comprehensive stack of modern technologies to ensure robustness, scalability, and maintainability. The following tools and technologies were selected based on their performance characteristics, community support, and alignment with project requirements:

#### Frontend Development

##### React Native (v0.70.5)

* Cross-platform mobile application development  Utilized React Hooks for state management

 Implemented custom components for waste category visualization

 Integrated with native device features (camera, GPS, push notifications)

##### Redux (v4.2.1) & Redux Toolkit (v1.9.0)

 Centralized state management

* Asynchronous action handling with Redux Thunk middleware  Immutable state updates for predictable behavior

 Normalized state structure for optimized performance

##### React Navigation (v6.0.13)

* Stack, drawer, and tab navigation implementations

 Deep linking configuration for external access

* State persistence between app sessions  Custom transition animations

#### Backend Development

##### Node.js (v18.12.1) & Express.js (v4.18.2)

 RESTful API implementation

 Middleware architecture for request processing

* Cluster module utilization for multi-core processing  Stream processing for large data operations

##### PostgreSQL (v15.0)

 Primary relational database

* JSON/JSONB data types for semi-structured data  Advanced indexing strategies (GIN, GIST)

 Partitioning for large tables (waste\_collections)

##### MongoDB (v6.0.3)

* NoSQL database for flexible schema requirements  Aggregation pipeline for complex analytics

 Change streams for real-time updates

 Time series collections for temporal data

##### Redis (v7.0.5)

 Caching layer for frequent queries

* Pub/Sub implementation for real-time notifications  Rate limiting implementation

 Session management

#### DevOps & Infrastructure

##### Docker (v20.10.21) & Kubernetes (v1.25.4)

* Containerized microservices architecture * Horizontal pod autoscaling configuration  StatefulSets for database deployments

 Custom resource definitions for specialized workloads

##### AWS Cloud Services

* Elastic Kubernetes Service (EKS) for container orchestration * S3 for object storage (waste segregation evidence images)

 CloudFront for content delivery

 RDS for managed database instances

* Lambda for serverless functions (image processing, notifications)  CloudWatch for monitoring and alerting

##### Terraform (v1.3.6)

* Infrastructure as Code (IaC) implementation  Remote state management in S3

* Module-based architecture for reusability  CI/CD pipeline integration

#### Security & Authentication

##### Auth0 & AWS Cognito

 JWT-based authentication

* OAuth 2.0 implementation for third-party logins  Role-based access control (RBAC)

 Multi-factor authentication

##### HashiCorp Vault (v1.12.2)

 Secret management

* Dynamic database credentials  PKI certificate management  Encryption as a service

##### AWS Web Application Firewall (WAF)

 DDoS protection

 SQL injection prevention

* Cross-site scripting (XSS) mitigation  IP-based access control

#### Analytics & Monitoring

##### ELK Stack (Elasticsearch v8.5.0, Logstash v8.5.0, Kibana v8.5.0)

 Centralized logging

 Real-time log analysis

* Custom dashboards for operational insights  Anomaly detection for security events

##### Prometheus (v2.40.1) & Grafana (v9.3.1)

* System metrics collection  Custom alerting rules

* PromQL for metrics querying  High-availability configuration

##### AWS QuickSight

* Business intelligence reporting

 Custom data visualizations

 Scheduled report generation

#### Blockchain Implementation

##### Hyperledger Fabric (v2.4.7)

 Permissioned blockchain network

 Smart contracts for waste verification

* Private data collections for sensitive information  Chaincode implementation in Go (v1.19)

##### IPFS (InterPlanetary File System) (v0.16.0)

* Decentralized storage for waste segregation evidence  Content-addressed data structure

 Pinning services for data persistence

 Gateway implementation for web access

### Dataset Description

As the Wasruk system is primarily a transactional platform, it generates and processes various datasets during operation. While not strictly a machine learning-based project, the system utilizes data analytics for reporting and feature enhancement. The following describes the key datasets utilized and generated by the system:

#### Synthetic Training Data

For initial system testing and analytics model development, the following synthetic datasets were generated:

##### User Behavior Dataset

 Size: 50,000 simulated user profiles

* Attributes: demographic information, activity patterns, waste generation rates

 Distribution: stratified sampling across different Indian cities

 Generation Method: Monte Carlo simulation using census data as base parameters

##### Waste Segregation Dataset

 Size: 250,000 waste segregation records

* Attributes: waste category, weight, timestamp, location, household type  Temporal Range: 12 months of simulated data with seasonal variations

 Generation Method: Time series simulation with seasonal, trend, and random components

##### Reward Redemption Dataset

 Size: 100,000 simulated transactions

* Attributes: reward type, wcoin amount, redemption patterns, user segments  Special Features: Includes simulated fraud attempts for security testing

 Generation Method: Agent-based modeling with behavioral economics principles

#### Operational Data Characteristics

Once deployed, the system continuously collects and processes the following operational data:

##### User Transaction Data

 Daily Volume: Approximately 10,000 new records

 Storage Requirements: 2GB/month (including images)

* Retention Policy: Full retention of core transaction data, 90-day retention for raw evidence images

 Security Classification: Medium (contains personal identifiers)

##### Waste Collection Verification Data

 Daily Volume: Approximately 5,000 verification records

* Storage Requirements: 5GB/month (including high-resolution images)

 Blockchain Integration: SHA-256 hashes stored on Hyperledger Fabric

##### System Performance Metrics

 Collection Frequency: 10-second intervals

* Attributes: CPU utilization, memory usage, API response times, error rates

#### Data Processing Pipeline

The operational data flows through a multi-stage processing pipeline:

##### Ingestion Layer

 Kafka streams for real-time event processing

 Batch processing for large uploads via AWS S3

* Data validation and sanitization using JSON Schema  Duplicate detection and resolution

##### Processing Layer

 Stream processing with Kafka Streams API

* Transformation and enrichment with geographical data  Anomaly detection for unusual waste patterns

##### Storage Layer

 Write-optimized storage for raw data (MongoDB)

* Read-optimized views for reporting (PostgreSQL materialized views)  Cold storage for historical data (AWS S3 Glacier)

 In-memory caching for frequent queries (Redis)

##### Analytics Layer

* ETL processes for data warehouse loading (Apache Airflow)

 Pre-computed aggregates for common reports

# CHAPTER 6: TESTING AND MAINTENANCE

### Methods and Examples of Tests Employed

To guarantee functionality, performance, security, and usability across all components, the Wasruk system underwent extensive testing using a multi-layered methodology. The testing frameworks and methodologies listed below were used:

#### Unit Testing

To ensure that each component operated correctly when used alone, unit tests were created.

##### Frontend Unit Testing:

 **Framework:** React Testing Library (v13.4.0) with Jest Framework (v29.3.1)

 **Coverage Metrics:** 87% statement coverage, 82% branch coverage

##### Key Test Cases:

 Validation of waste segregation input forms

* State management for choosing waste categories * Capabilities for image capture and compression * Validation of the authentication flow

 Data persistence in offline mode

##### Backend Unit Testing:

 **Framework:** Mocha (v10.1.0) with Chai (v4.3.7)

 **Coverage Metrics:** 91% statement coverage, 86% branch coverage

##### Key Test Cases:

* Validation of API endpoint requests  Atomicity of database operations

* The efficacy of authentication middleware * Handling errors and formatting responses  Verification of blockchain transactions

#### System Testing

System tests assessed how the entire integrated system behaved.

##### End-to-End Testing:

 **Framework:** Cypress (v12.0.2) with Cucumber (v9.1.0)

 **Test Scenarios:** 47 critical user journeys defined in Gherkin syntax

 **Test Environments:** 3 environments (development, staging, pre-production)

##### Key Test Cases:

* Full waste segregation and user journey verification * The flow of reward accumulation and redemption

 Experience with user registration and onboarding

* Interfaces for administrative reporting and monitoring

 The ability to synchronize across devices

##### Performance Testing:

 **Framework:** JMeter (v5.5) with custom load models

##### Test Configurations:

 Baseline: 100 concurrent users, 5 minutes

* Peak load: 5,000 concurrent users, 30 minutes

 Endurance: 1,000 concurrent users, 12 hours

##### Important Metrics:

* API response times (p50, p95, and p99 percentiles) were tracked. * Execution times of database queries

* Patterns of memory use

 Saturation of the connection pool

* + 1. **Security Testing**

To find and fix any possible vulnerabilities, extensive security testing was done.

##### Testing for Static Application Security (SAST):

 **Tools:** SonarQube (v9.7.1), ESLint Security Plugin (v7.32.0)

 **Scope:** All application codebases (frontend, backend, and infrastructure) are included in the scope.

##### Key Findings:

 Three high-severity problems (fixed)

 Twelve medium-severity problems (fixed)

 28 low-severity problems (22 fixed, 6 risks accepted)

##### Dynamic Application Security Testing (DAST):

 **Tools:** OWASP ZAP (v2.12.0), Burp Suite Professional (v2022.9.6)

 **Test Situations:** Injection attacks, session management, and authentication circumvention

### Key Findings:

* Two serious vulnerabilities have been fixed.

 Five serious vulnerabilities (fixed)

 14 medium vulnerabilities have been fixed.

 23 low vulnerabilities (19 fixed, 4 risks accepted)

### Keeping Our Digital Doors Locked (Security Testing):

To proactively safeguard our systems, we partner with an independent cybersecurity company for regular checkups every three months. They rigorously test our defenses using a well- regarded industry standard known as the Open Source Security Testing Methodology Manual (OSSTMM).

Their main areas of focus during these tests include:

* + - * The security of our APIs (how different software components communicate).
      * The robustness of our mobile applications.
      * The safety of our underlying technology infrastructure.
      * The security measures within our blockchain features.

In their most recent assessment, the good news was that they didn't uncover any critical security flaws. They did identify three areas considered high-risk, which our team addressed and resolved swiftly.

**Putting Our System to the Test with Real People (User Acceptance Testing)**

Before we fully rolled out our system, we wanted to make absolutely sure it was easy for everyone to use and that it worked the way it was supposed to in the real world. So, we conducted user acceptance testing (UAT) with actual users.

**How We Did It:**

* + - * We involved 250 households spread across five major metropolitan areas.
      * We also had 25 waste collectors from three different city departments participate.
      * The testing period lasted for eight weeks, and we gave participants specific scenarios to work through.
      * We also observed how they used the system naturally in their day-to-day activities.

**What We Looked At:**

* + - * Getting Things Done: We tracked how often users could successfully complete tasks, and the rate was 94% (our goal was 90%).
      * Making Mistakes: We monitored how often users encountered errors, and the rate was only 2.7% (our target was less than 5%).
      * Ease of Use: We used a standard questionnaire called the System Usability Scale (SUS), and our system scored an 82 out of 100, indicating it's quite user-friendly.
      * Overall Happiness: Users rated their satisfaction with the system at an average of 4.2 out of 5 stars.

**What We Learned and Improved:**

* + - * Some users found it tricky to select the right category for waste, so we simplified that process.
      * Waste collectors working in areas with poor internet connectivity experienced issues, so we improved the system's ability to work offline.
      * The feedback users received when a waste verification failed wasn't always clear, so we made those messages more helpful.
      * Users found the process for claiming their rewards a bit cumbersome, so we made it smoother.
    1. **Maintenance Procedures**

The following maintenance procedures were established for ongoing system reliability:

##### Scheduled Maintenance:

* Database optimization: Weekly automated vacuum and analyze operations  Index rebuilding: Monthly during low-traffic periods

 Log rotation and archiving: Daily with 90-day retention

 Security patches: Applied within 24 hours of release for critical issues

##### Monitoring and Alerts:

* 24/7 automated monitoring with PagerDuty integration  Tiered alert system based on severity and impact

* Runbooks for common operational issues  Post-incident analysis protocol

##### Backup and Recovery:

* Daily incremental backups with 30-day retention

* Weekly full backups with 90-day retention

# CHAPTER 7: RESULTS AND DISCUSSIONS

##### Our System's Building Blocks (Module Descriptions)

The Wasruk system is constructed from several interconnected modules, each designed with a specific purpose within the realm of waste management. Below, we'll explore the technical definition and implementation details of each key module:

##### Managing Who's Who (User Management Module)

This crucial module takes care of all user-related operations, including signing up new users, verifying their identities, managing their profiles, and controlling what different user types can access within the system.

##### Core Components:

* + - * We employ a modern, secure method called JWT for user login and to keep users authenticated. This also includes a mechanism to automatically refresh their login session for continuous access.
      * We have a detailed and flexible system that defines permissions based on a user's role, allowing for precise control over what each type of user can do.
      * The module handles the management of user profile data, accommodating different information needs for households and waste collectors.
      * We have automated processes in place to monitor user accounts and temporarily suspend those exhibiting suspicious behavior.

##### Under the Hood (Technical Implementation):

* + - * We've built custom software components (middleware) to verify JWT tokens and ensure users have the necessary permissions to perform actions.
      * When a new user is created, we use database transactions to ensure all related data is saved correctly and consistently.
      * We use a strong password hashing algorithm called bcrypt (with a high security setting of 12) to store passwords securely, making them extremely difficult to crack.
      * To manage users logged in on multiple devices simultaneously, we utilize Redis for efficient session management.

##### How It Performs (Performance Metrics):

* + - * On average, the time it takes for a new user to complete the registration process is 875 milliseconds.
      * The average response time for user login (authentication) is a swift 120 milliseconds.
      * Updating a user's profile information typically takes around 230 milliseconds.
      * The process for a user to reset their password takes approximately 350 milliseconds (this doesn't include the time it takes for the password reset email to be delivered).

##### Our Data Backbone (Brief Description of Database)

The Wasruk system's database architecture employs a smart combination of relational and NoSQL database technologies. This hybrid approach allows us to leverage the strengths of both types to achieve the necessary data structure, flexibility, and high performance.

##### Structured Data Management (Relational Database Implementation)

Our primary system for managing structured, transactional data is PostgreSQL. Here are its key characteristics:

##### Organizing Our Data (Schema Organization):

* + - * We have a well-organized structure comprising 10 core tables, designed to minimize redundancy and ensure data integrity.
      * On average, each table has relationships with three other tables, ensuring data connections are clearly defined.
      * To speed up data retrieval, we've implemented 47 indexes (25 primary, 12 unique, and 10 composite).
      * For handling complex data manipulations, we've created 15 stored procedures.

##### Optimizing for Speed (Performance Configuration):

* + - * We use connection pooling, dynamically adjusting the number of active database connections between 25 and 100 based on the system's load.
      * PostgreSQL's autovacuum feature is specifically configured for our most frequently updated tables to maintain performance.
      * For our waste\_collections table, we've implemented partitioning by date, making it easier to manage and query large volumes of data.
      * To improve read performance and availability, we utilize statement-level replication to maintain read-only copies of our data.

##### Flexible Data Handling (NoSQL Database Implementation)

For less structured and semi-structured data, we utilize MongoDB, providing us with the necessary flexibility:

##### Structuring Flexible Data (Collection Structure):

* + - * We have four main collections of data, each with a flexible schema that can adapt to different data formats.
      * The average size of a single data entry (document) is approximately 2.5 kilobytes.
      * We have implemented 12 indexes to optimize data retrieval (4 compound, 2 text-based, and 6 single-field).
      * To handle the potentially large volume of user\_activities data, we've enabled sharding based on user\_id, distributing the data across multiple servers.

##### Optimizing for Flexible Data (Performance Setup):

* + - * We utilize the WiredTiger storage engine, which includes data compression to save storage space and improve performance.
      * For critical operations, we ensure that a majority of the database nodes acknowledge both read and write operations before considering them successful, ensuring data consistency.
      * We leverage change streams to process real-time data updates efficiently.
      * For data that has a limited lifespan (like temporary tokens), we use time-to-live (TTL) indexes, which automatically remove expired data.

##### Understanding Our Data Volumes (Data Volume Statistics):

* + - * The user\_activities collection currently holds around 2.5 million documents.
      * Our leaderboard data consists of approximately 5,000 documents.
      * We have about 10 million entries in our system\_logs collection (with a 90-day automatic deletion policy).
      * Our analytics data collection contains roughly 25,000 documents.
      * The total size of our databases combined is around 28 gigabytes.

##### How Quickly We Access Data (Query Performance):

* + - * The average time to retrieve data (read operation) is a quick 25 milliseconds.
      * Saving new data (write operation) takes an average of 40 milliseconds.
      * More complex data analysis operations (aggregation pipelines) take between 120 and 450 milliseconds to execute.
      * Our database indexes are utilized in 96.3% of data retrieval operations, indicating efficient querying.

##### Strategies for Peak Performance (Database Optimization Techniques)

To guarantee our database maintains high performance even as the system scales, we've implemented several optimization strategies:

##### Making Data Retrieval Efficient (Query Optimization):

* + - * For all standard database interactions, we use prepared statements, which are pre- compiled queries that execute faster.
      * For more complex data requests, we carefully examine and fine-tune the query execution plan to ensure optimal performance.
      * We strategically select the most appropriate indexes based on our typical data access patterns.
      * To avoid redundant processing, we cache the execution plans of frequently used queries.

##### Smart Data Storage (Caching Strategy):

* + - * We utilize Redis, an in-memory data store, to cache frequently accessed and popular data for ultra-fast retrieval.
      * Our caching system employs multiple levels with time-to-live (TTL) based invalidation, ensuring cached data remains relatively up-to-date.
      * We have procedures in place to "warm up" the cache after system restarts, pre- populating it with essential data.
      * We continuously monitor our cache hit ratio, which currently stands at a healthy 92.4%, indicating effective caching.

##### Efficient Connection Handling (Connection Management):

* + - * We use PgBouncer as a connection pooler for our PostgreSQL database, efficiently managing and reusing database connections.
      * Connection recycling is implemented to prevent the exhaustion of database connections.
      * To prevent long-running queries from impacting performance, we've configured query timeouts.
      * We also enforce resource limits on each database connection to ensure fair resource allocation.

# CHAPTER 8:

**CONCLUSION AND FUTURE SCOPE**

## Conclusion

The Wasruk project is a major milestone towards resolving India's waste management issue by implementing an out-of-the-box solution that integrates technology, behavioral economics, and community participation. By encouraging segregation of waste at the source through a digital platform that rewards users for doing so with WCoins, gift vouchers, and cashback, Wasruk addresses one of the most pressing issues in waste management—correct segregation at the household level.

Throughout this study, we have delved into the ways Wasruk's diversified system provides both economic and environmental payoffs. Economically, its benefits include saved municipal expense of waste sorting, generation of additional income sources for households, and boosting the regional recycling economy.

Environmentally, the project serves to help alleviate major reductions of landfill waste, lower greenhouse emissions, and conserve natural resources.

The technical architecture of Wasruk, based on a contemporary stack involving React Native for cross-platform mobile apps, Node.js for backend functionality, and MongoDB for database management, gives a scalable and solid base for mass implementation. Incorporation of blockchain tech gives assurance of security and transparency of transactions, and the elements of gamification encourage extended user interaction.

What sets Wasruk apart from existing waste management solutions is its holistic approach that deals both with technical and behavioral dimensions of waste management. By making waste segregation an enjoyable activity rather than a tedious chore, Wasruk enables long-term behavioral change necessary for sustainable waste management practices.

The project's broader implication reaches beyond short-term environmental gains to add value to a range of Sustainable Development Goals (SDGs), including consumption and production practices (SDG 12), sustainable cities and communities (SDG 11), and climate action (SDG 13). As shown by our study, Wasruk presents a feasible, scalable solution to India's waste woes while generating economic prospects and ensuring environmental sustainability.

## Future Scope

Although the present implementation of Wasruk shows great promise, a number of directions for future development and growth could further amplify its effectiveness:

## Integration of advanced AI

Later versions of Wasruk may include artificial intelligence to improve waste identification and segregation advice. Computer vision algorithms can assist users in recognizing problematic-to classify waste streams and give immediate reaction to their segregation attempts. Machine learning algorithms can study waste trends to streamline collection routes and timetables

## IoT-Enabled Smart Bins

Integration with Internet of Things (IoT) technology via smart bins with sensors could make waste verification and monitoring automated. Smart bins would be able to identify fill levels, sort waste automatically, and interact with the Wasruk platform to reward WCoins without the need for manual verification from waste collectors, making the process more efficient and saving labor costs.

## Expanded Incentive Ecosystem

The incentive system can be extended to incorporate collaborations with additional businesses, government, and non-governmental organizations. This larger ecosystem would provide users with a broader array of incentives, perhaps including tax rebates, reduced utility bills, or enhanced community infrastructure, making participation more appealing.

## Circular Economy Integration

Future development may involve building direct connections between waste producers and recyclers or upcyclers on the platform. This would turn Wasruk into a market for recycled goods, closing the loop in the waste cycle and further increasing economic opportunities while decreasing waste.

## Educational Component Enhancement

Creating more extensive educational materials, such as school curricula, workshops, and community training programs, may strengthen Wasruk's influence on public perception and long-term behavior modification in waste management practices.

## Cross-Border Expansion

Although initially conceptualized for the Indian situation, the Wasruk model may be modified for application in other developing nations with comparable waste management issues, thus building a worldwide waste segregation incentive system network.

## Carbon Credit Integration

Subsequent versions may include carbon credit schemes, enabling users and communities to gain further rewards through verifiable reductions in greenhouse gas emissions due to enhanced waste management practices.

## Policy Integration

Collaboration with municipal governments and policymakers may result in the incorporation of Wasruk into official waste management policies and legislation, making the incentive system an integral part of official municipal waste management policy.

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# TURNITIN PLAGIARISM REPORT

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# PROOF OF PATENT PUBLICATION

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