Riphah International University Lahore, Pakistan

Riphah School of Computing & Innovation

Semester Project

Complete Document

Clean Lahore Smart Waste Management System

Project Team

Student Name	Student ID	Program	Contact Number	Email Address
HAFIZ AHSAN ARSHAD	48698	BSSE	03078995505	48698@students.riphah.edu.pk
MAHNOOR QURESHI	48038	BSSE	03254020380	48038@students.riphah.edu.pk

{Project Supervisor}
Mam Aroon Arshad

1.1. System Features

1.1.1. Smart Dustbin Management

- **REQ-SF1-1:** The system shall detect when a smart dustbin is 90% full using ultrasonic sensors.
- **REQ-SF1-2:** The system shall send bin-full alerts to waste collection teams in real time.
- **REQ-SF1-3:** The system shall display bin status to citizens via the mobile application.

1.1.2. Vehicle Tracking and Route Optimization

- **REQ-SF2-1:** The system shall track waste collection vehicles using GPS.
- **REQ-SF2-2:** The system shall calculate and assign optimized collection routes using AI.
- **REQ-SF2-3:** The system shall display vehicle locations to citizens in the mobile app.

1.1.3. Citizen Engagement App

- **REQ-SF3-1:** The system shall allow citizens to submit complaints with images and GPS location.
- **REQ-SF3-2:** The system shall update complaint statuses in real-time within the app.
- **REQ-SF3-3:** The system shall assign reward points to users based on engagement activities.

1.1.4. Surveillance and Detection

- **REQ-SF4-1:** The system shall detect garbage accumulation using AI-powered CCTV and drone footage.
- **REQ-SF4-2:** The system shall send alerts to the control center

upon detecting illegal dumping.

1.1.5. Workforce Management

- **REQ-SF5-1:** The system shall verify worker attendance using facial recognition**.**
- **REQ-SF5-2:** The system shall assign daily tasks and track completion via QR code scans**.**

1.1.6. Command & Control Center

- **REQ-SF6-1:** The system shall provide a centralized dashboard for monitoring bins, staff, vehicles, and complaints**.**
- **REQ-SF6-2:** The system shall use AI to optimize resource scheduling and task allocation.

1.1.7. Robotic & Electric Cleaning Devices

- **REQ-SF7-1:** The system shall operate robotic cleaning devices in narrow streets based on AI-generated schedules.
- **REQ-SF7-2:** The system shall allow manual overrides for electric mini sweepers.

1.1.8. Auto Fine System

- **REQ-SF8-1:** The system shall detect littering incidents using AI from surveillance feeds**.**
- **REQ-SF8-2:** The system shall send fine notifications to violators via SMS or app**.**

1.1.9. Virtual Assistant

- **REQ-SF9-1:** The system shall respond to citizen queries using an in-app AI chatbot.
- **REQ-SF9-2:** The system shall support Urdu and English for voice and text input.

1.1.10. Predictive Maintenance

- **REQ-SF10-1:** The system shall monitor equipment health and usage patterns.
- **REQ-SF10-2:** The system shall alert maintenance teams about potential breakdowns in advance.

1.1.11. Community Dashboard

- **REQ-SF11-1:** The system shall display neighborhood cleanliness scores based on waste data.
- **REQ-SF11-2:** The system shall update and publish the scores weekly on a public leaderboard.

1.1.12. Government Integration

- **REQ-SF12-1:** The system shall verify user identity using NADRA's citizen database.
- **REQ-SF12-2:** The system shall integrate with Punjab Government's e-payment system for fines and services.

1.2. Other Nonfunctional Requirements

1.2.1. Performance

- **REQ-NF1-1:** The system shall display bin status, vehicle location, and complaint updates in under 5 seconds.
- **REQ-NF1-2:** The system shall support at least 5,000 concurrent users without performance degradation**.**
- **REQ-NF1-3:** The system shall send AI-based alerts (e.g., litter detection) within 10 seconds of event detection.

1.2.2. Reliability

- **REQ-NF2-1:** The system shall maintain 99.9% uptime availability throughout the year.

- **REQ-NF2-2:** The system shall perform automatic daily backups of critical data (e.g., complaints, bin levels).
- **REQ-NF2-3:** The system shall ensure core functionalities remain operational during partial system failures.

1.2.3. Security

- **REQ-NF3-1:** The system shall encrypt all data transmissions between the mobile app, dashboard, and devices using HTTPS/TLS.
- **REQ-NF3-2:** The system shall protect user data, including names, images, and complaint logs, from unauthorized access.
- **REQ-NF3-3:** The system shall enforce secure access through two-factor authentication and role-based access control (RBAC).

1.2.4. Usability

- **REQ-NF4-1:** The system shall provide a user-friendly interface with clearly labeled icons and large buttons**.**
- **REQ-NF4-2:** The system shall allow users to submit a complaint or recycle item in no more than 3 steps.
- **REQ-NF4-3:** The virtual assistant shall support voice interaction in both Urdu and English.

1.2.5. Scalability

- **REQ-NF5-1:** The system shall scale to support up to 1 million users, 20,000 smart bins, and 100 collection trucks.
- **REQ-NF5-2:** The system shall allow expansion to new cities or districts without significant re-engineering.

1.2.6. Maintainability

- **REQ-NF6-1:** The system shall modularize features (e.g., chatbot, AI surveillance, QR verification) to enable independent updates**.**
- **REQ-NF6-2:** The system shall update AI models monthly using new datasets.
- **REQ-NF6-3:** The system shall log all errors and exceptions for future debugging and maintenance purposes.

1.2.7. Interoperability

- **REQ-NF7-1:** The system shall interoperate with NADRA APIs for citizen verification.
- **REQ-NF7-2:** The system shall integrate with Punjab Government's e-payment platform for fine collection and reward distribution.
- **REQ-NF7-3:** The system shall enable data sharing with other authorized government applications as needed.

1.2.8. Accessibility

- **REQ-NF8-1:** The system shall comply with accessibility standards to support users with visual or mobility impairments.
- **REQ-NF8-2:** The system shall support screen readers and voice commands for navigation.
- **REQ-NF8-3:** The virtual assistant shall support multiple languages for inclusive communication.

2.1 Competitive Analysis/ Existing Application

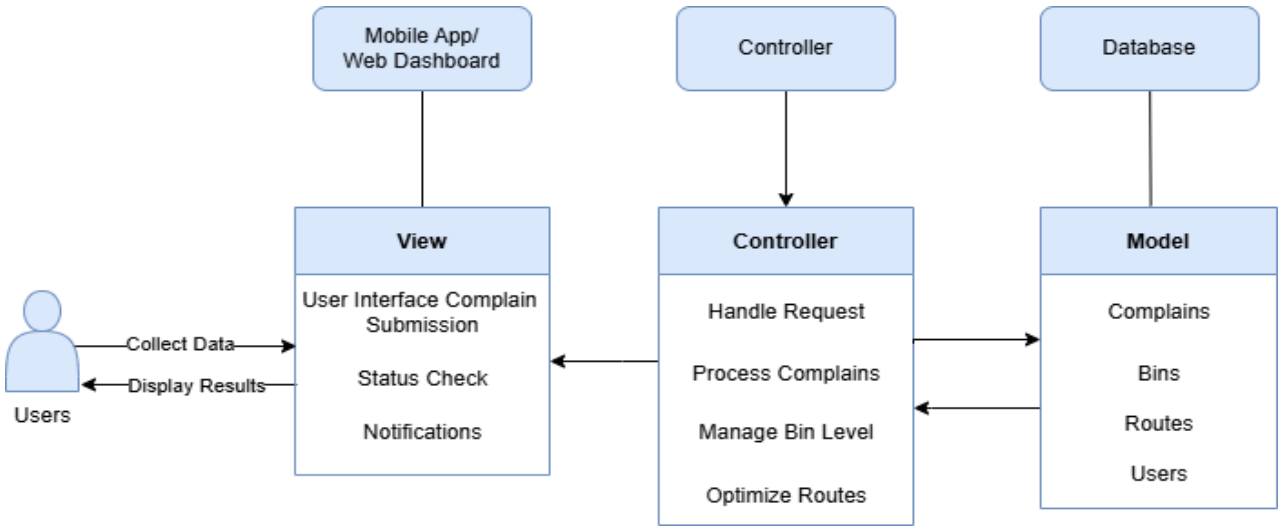
Feature / Functionality	Bigbelly (USA)	Smart Bin (Ireland)	Eco Trash (Canada)	Evreka (Global)	Clean Lahore (LWMC)
Smart Dustbins with Sensors & RFID	✓	✓	✗	✓	✓
GPS-Tracked Vehicles & AI Route Optimization	✗	✗	✓	✓	✓
Citizen Mobile App with Complaint + Reward System	✗	✗	✗	✗	✓
AI Surveillance via Drones & CCTV	✗	✗	✗	✗	✓
AI-Based Workforce Management	✗	✗	✗	✗	✓
Command & Control Center	✓	✓	✓	✓	✓
Electric Mini Sweepers & Robotic Cleaning Devices	✗	✗	✗	✗	✓
Automated Fine System	✗	✗	✗	✗	✓
Virtual AI Assistant (Chatbot + Voice)	✗	✗	✗	✗	✓
Predictive Maintenance (AI for Fleet/Devices)	✗	✗	✗	✗	✓
Neighborhood Cleanliness Score Dashboard	✗	✗	✗	✗	✓
Integration with Government Systems (NADRA, e-Payment)	✗	✗	✗	✗	✓
Simple & Fast User Interface	✗	✗	✗	✓	✓
Voice & Urdu Support for Accessibility	✗	✗	✗	✗	✓
Scalable to Large Cities and Users	✗	✓	✓	✓	✓
Data Security (Encryption + 2FA)	✓	✓	✗	✓	✓

2.2 Current Technology Stack & Architecture Diagram

2.2.1. Current Technology Stack

Layer	Technology Used
Frontend (User Interface)	Flutter (for cross-platform mobile app), React (for admin web dashboard)
Backend (APIs & Logic)	Node.js / Express or Django / Flask (REST APIs), Firebase Cloud Functions
Database	Firebase Realtime DB / Fire store (for mobile app), PostgreSQL / MongoDB (admin)
IoT & Devices	Ultrasonic Sensors, RFID Modules, GPS Modules, Air Quality Sensors
AI & Machine Learning	TensorFlow / OpenCV (for object detection, drone surveillance, predictions)
Cloud Services	Google Cloud Platform / AWS / Azure (hosting, storage, analytics)
Authentication	Firebase Auth / OAuth 2.0 / NADRA API Integration
Notifications	Firebase Cloud Messaging (FCM), SMS Gateway
Payments Integration	Punjab Government e-Payment APIs
Data Analytics	Google Big Query / Power BI / custom dashboards
Security	HTTPS, TLS, JWT, Role-Based Access Control (RBAC), 2-Factor Authentication

2.2.2. Architecture Diagram



3.1. SOFTWARE DEVELOPMENT LIFE CYCLE

Given the complexity, molecularity, and evolving nature of your Waste Management System, the best-suited Software Development Life Cycle (SDLC) model is the Agile SDLC Model.

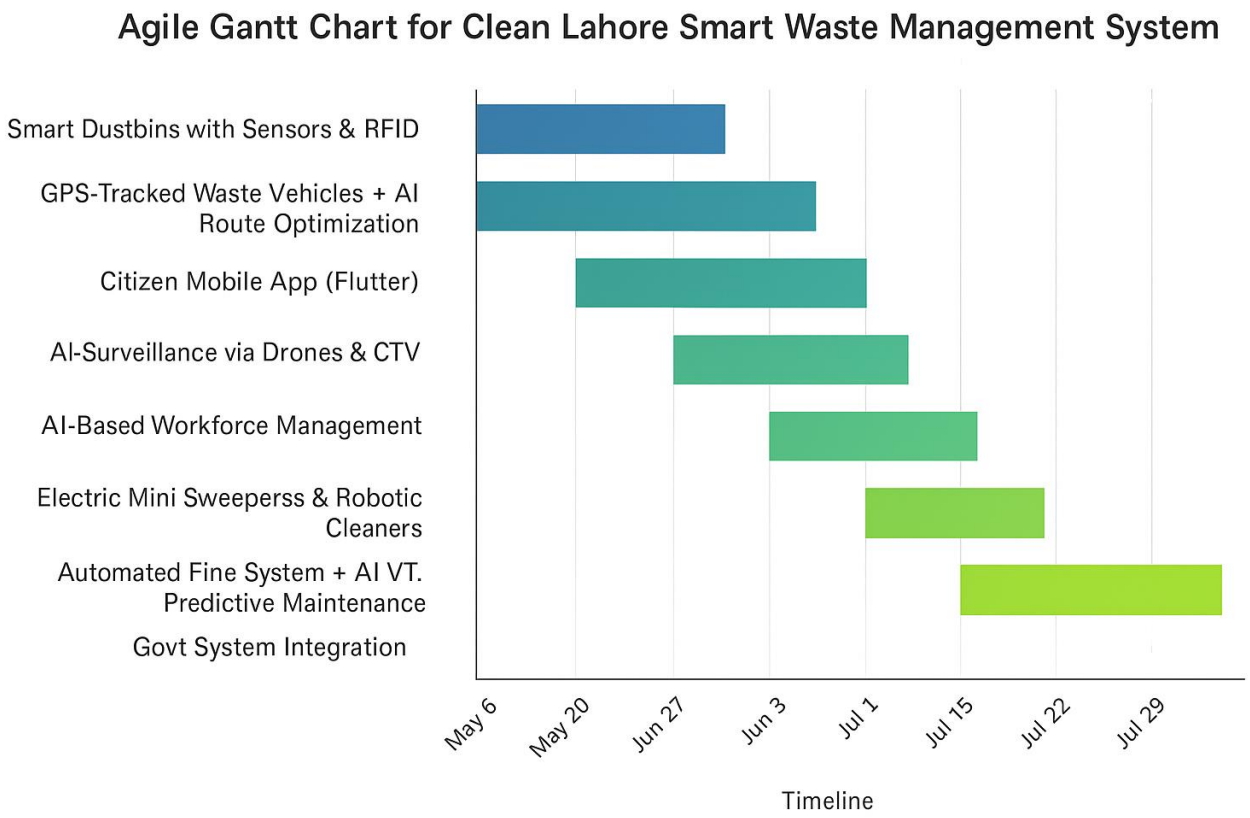
Why Agile is Best for Your System?

Reason	Explanation
Modular design	Each module (Smart Bins, App, AI Surveillance, etc.) can be built and tested independently
Rapid Iteration	Features like AI and routing can be continuously improved
User Feed Back	Citizens and municipal staff can give real-world feedback during sprints
Scalability	New cities, bins, or drone units can be added easily
Collaboration	Hardware, AI, App, and Backend teams work in parallel

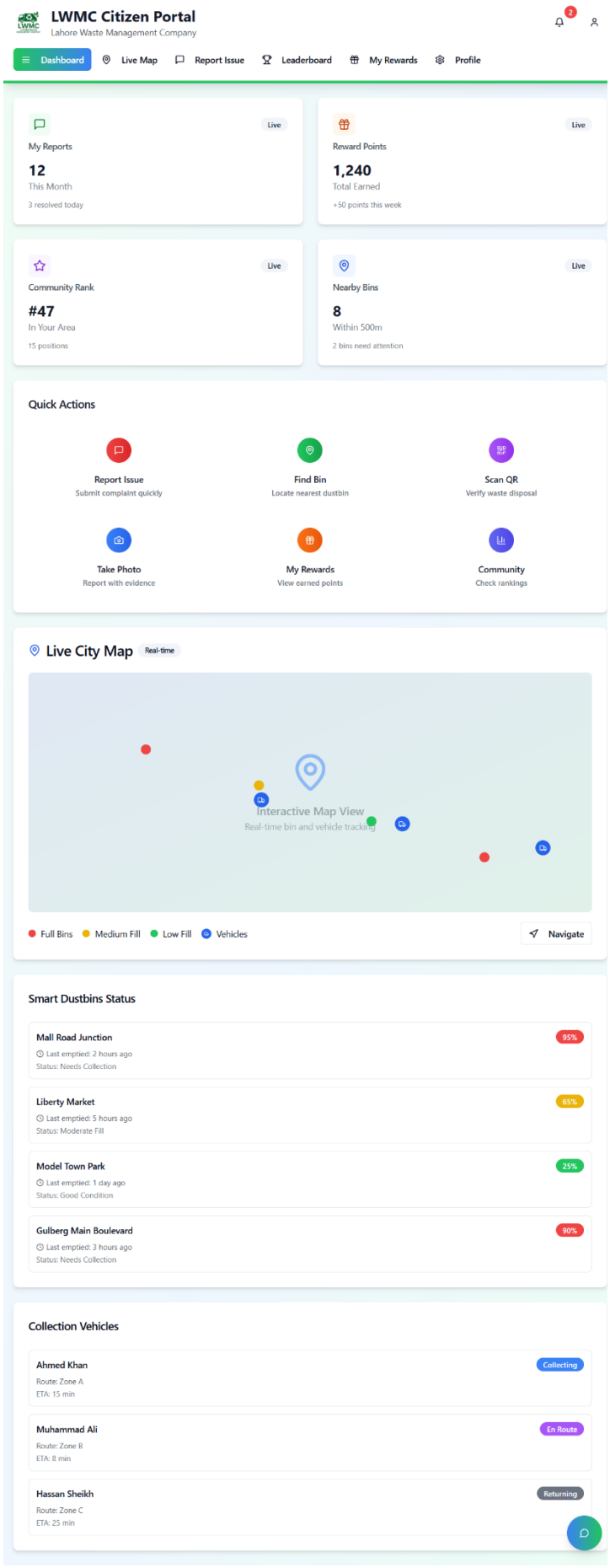
Why Not Other Models?

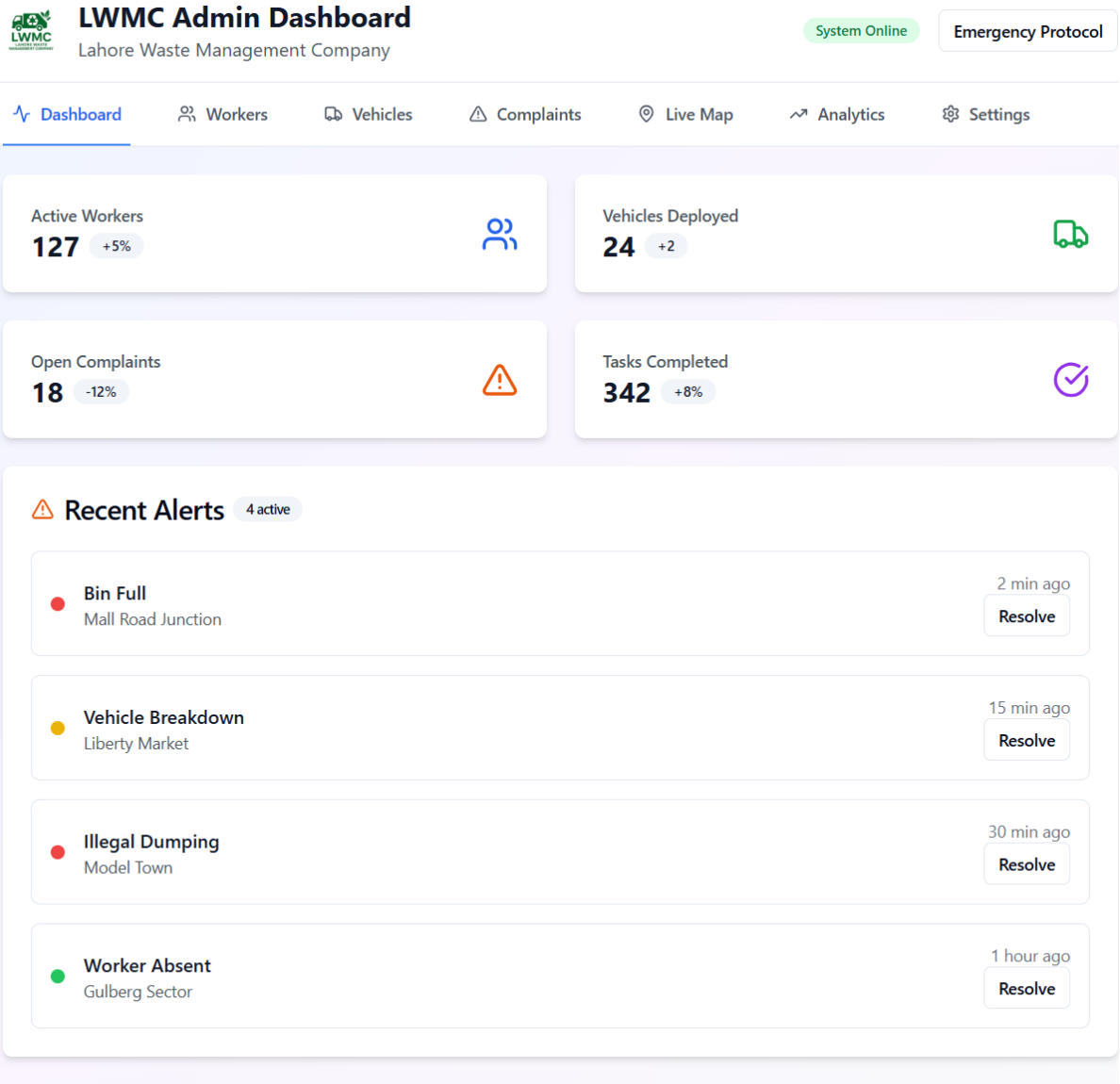
- **Waterfall:** Too sequential; cannot adapt to dynamic real-world inputs
- **Spiral:** Too complex for a citizen utility app
- **V-Model:** Best for strict validation systems, not adaptable for smart city Modules

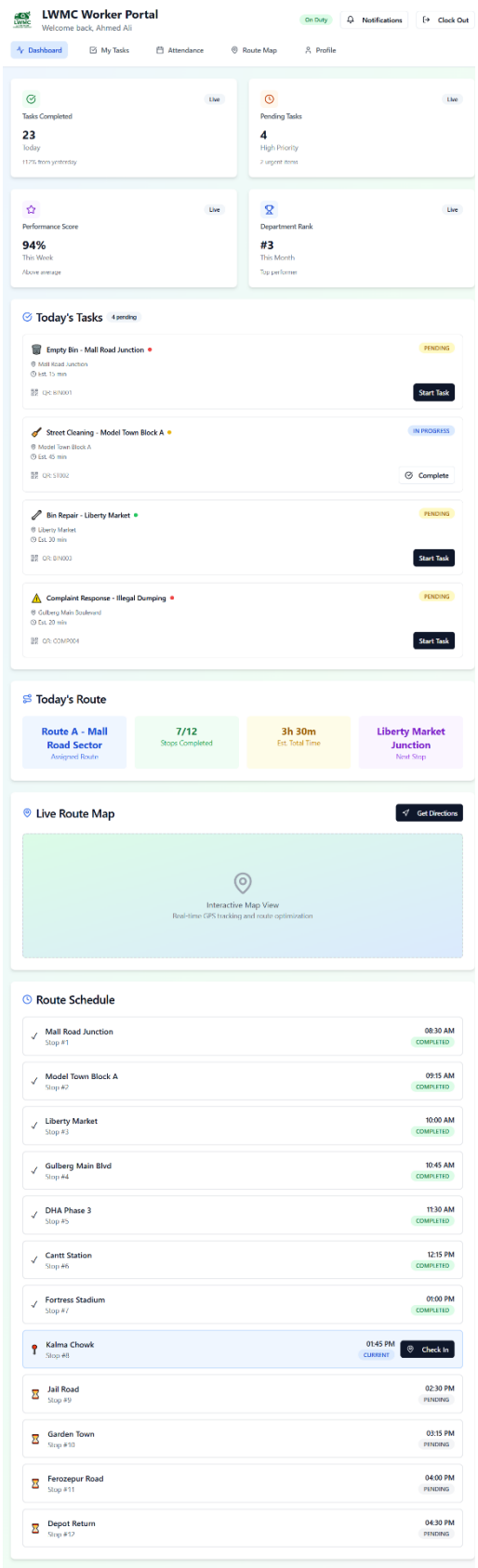
3.2 Gantt Chart



3.3 Prototype


LWMC Citizen Portal
Lahore Waste Management Company
2
Dashboard
Live Map
Report Issue
Leaderboard
My Rewards
Profile
Live
My Reports
12
This Month
3 resolved today
Live
Reward Points
1,240
Total Earned
+50 points this week
Live
Community Rank
#47
In Your Area
15 positions
Live
Nearby Bins
8
Within 500m
2 bins need attention
Quick Actions
Report Issue
Submit complaint quickly
Find Bin
Locate nearest dustbin
Scan QR
Verify waste disposal
Take Photo
Report with evidence
My Rewards
View earned points
Community
Check rankings
Live City Map
Real-time
Interactive Map View
Real-time bin and vehicle tracking
Full Bins
Medium Fill
Low Fill
Vehicles
Navigate
Smart Dustbins Status
Mall Road Junction
95%
Last emptied: 2 hours ago
Status: Needs Collection
Liberty Market
65%
Last emptied: 5 hours ago
Status: Moderate Fill
Model Town Park
25%
Last emptied: 1 day ago
Status: Good Condition
Gulberg Main Boulevard
90%
Last emptied: 3 hours ago
Status: Needs Collection
Collection Vehicles
Ahmed Khan
Collecting
Route: Zone A
ETA: 15 min
Muhammad Ali
En Route
Route: Zone B
ETA: 8 min
Hassan Sheikh
Returning
Route: Zone C
ETA: 25 min


LWMC Admin Dashboard
Lahore Waste Management Company
System Online
Emergency Protocol
Dashboard
Workers
Vehicles
Complaints
Live Map
Analytics
Settings
Active Workers
127
+5%
Vehicles Deployed
24
+2
Open Complaints
18
-12%
Tasks Completed
342
+8%
Recent Alerts
4 active
Bin Full
Mall Road Junction
2 min ago
Resolve
Vehicle Breakdown
Liberty Market
15 min ago
Resolve
Illegal Dumping
Model Town
30 min ago
Resolve
Worker Absent
Gulberg Sector
1 hour ago
Resolve


LWMC Worker Portal
Welcome back, Ahmed Ali
On Duty
Notifications
Clock Out
Dashboard
My Tasks
Attendance
Route Map
Profile
Live
Tasks Completed
23
today
11.7% from yesterday
Live
Pending Tasks
4
High Priority
2 urgent items
Live
Performance Score
94%
This Week
Above average
Live
Department Rank
#3
This Month
Top performer
Today's Tasks
4 pending
Empty Bin - Mall Road Junction
Mall Road Junction
Est. 15 min
QR: BIN001
PENDING
Start Task
Street Cleaning - Model Town Block A
Model Town Block A
Est. 45 min
QR: ST002
IN PROGRESS
Complete
Bin Repair - Liberty Market
Liberty Market
Est. 30 min
QR: BIN003
PENDING
Start Task
Complaint Response - Illegal Dumping
Gulberg Main Boulevard
Est. 20 min
QR: COMP004
PENDING
Start Task
Today's Route
Route A - Mall Road Sector
Assigned Route
7/12
Stops Completed
3h 30m
Est. Total Time
Liberty Market Junction
Next Stop
Live Route Map
Get Directions
Interactive Map View
Real-time GPS tracking and route optimization
Route Schedule
Mall Road Junction
Stop #1
08:30 AM
COMPLETED
Model Town Block A
Stop #2
09:15 AM
COMPLETED
Liberty Market
Stop #3
10:00 AM
COMPLETED
Gulberg Main Blvd
Stop #4
10:45 AM
COMPLETED
DHA Phase 3
Stop #5
11:30 AM
COMPLETED
Cantt Station
Stop #6
12:15 PM
COMPLETED
Fortress Stadium
Stop #7
01:00 PM
COMPLETED
Kalma Chowk
Stop #8
01:45 PM
CURRENT
Check In
Jail Road
Stop #9
02:30 PM
PENDING
Garden Town
Stop #10
03:15 PM
PENDING
Ferozepur Road
Stop #11
04:00 PM
PENDING
Depot Return
Stop #12
04:30 PM
PENDING

3.4 Business Plan

3.4.1. The Business Opportunity

Problem Statement:

Lahore suffers from outdated waste management practices leading to overflowing bins, inefficient collection routes, low citizen participation, and environmental hazards. There is no existing smart platform integrating IoT, AI, and citizen reporting into a single system.

Pain Points Solved:

- Overflowing public bins
- Poor garbage collection scheduling
- Minimal citizen engagement
- Illegal dumping detection
- Inefficient route optimization
- Low accountability of waste collection staff

3.4.2. Company Description

What We Do:

Clean Lahore is a comprehensive AI & IoT-powered solution that provides:

- Smart Dustbins with real-time fill-level sensing and alerts
- GPS-tracked vehicles with AI route optimization
- Mobile App (Flutter) for citizen complaints, rewards & information
- AI-enabled drones & CCTV surveillance to monitor illegal waste dumping
- Workforce management through facial recognition & QR-code

verification

Core Solutions:

- Smart bins + sensor integration
- Real-time control dashboard
- Citizen mobile app (complaints, rewards)
- AI surveillance (drones, CCTV)
- Predictive maintenance & automated fine system

3.4.3. Industry Analysis

Industry: Gov Tech / Civic Tech — Smart Urban Waste Management

Competitors:

- Local: LWMC (manual system)
- International: Bigbelly, Ecube Labs, SmartBin

Success Factors:

- Seamless public-private tech integration
- Gamified citizen participation
- Scalable & cost-effective IoT-AI deployment
- Reliable real-time data and AI predictions
- Government partnership potential

3.4.4. Implementation Timeline

Phase	Timeline	Key Activities
Planning & Design	Month 1	Feature definition, UI/UX design, system architecture
MVP Development	Month 2–3	Smart bin prototype, citizen app, control dashboard
Pilot Testing	Month 4–5	Deployment of 20+ smart bins, mobile app release
Evaluation	Month 6	Performance analysis, public feedback collection
City-Wide Rollout	Month 7+	Large-scale deployment, commercial partnerships

3.4.5. Team

Role	Responsibilities
Project Lead	Overall system integration and execution
IoT Engineer	Hardware design (bins, sensors, drones)
AI Developer	Model training (image recognition, routing AI)
App Developer	Flutter-based citizen & admin apps
UI/UX Designer	User-centered design for apps & dashboards
Marketing Lead	Awareness campaigns, citizen onboarding

Why Us?

A multi-disciplinary team of Computer Science graduates skilled in Flutter, Node.js, AI, IoT, and system design — committed to making Lahore cleaner and smarter.

3.4.7. Target Market

Primary Targets:

- Lahore Waste Management Company (LWMC)
- City Municipal Corporations
- Hospitals, Commercial Markets
- NGOs focused on environment & sustainability

Buyer Personas:

- City Planners: Urban development & smart city projects
- Environmentally Aware Citizens: Clean neighborhood advocates
- Event Organizers: Waste management for public events
- NGOs: Data for environmental studies

3.4.8. Marketing Plan

Channels:

- Social Media (Instagram, TikTok, Facebook)
- University & School Awareness Drives
- Government Collaboration (LWMC, Punjab Govt)
- Referal & Gamification within App

Conversion Strategy:

- Reward points for app downloads
- Cleanliness leaderboard for communities
- QR scanning challenges for citizens

3.5. Financial Summary Plan

1. Objective

To deploy a smart waste management system in Lahore using IoT, AI, and real-time tracking. This includes smart bins, GPS-tracked waste collection vehicles, drones, and citizen engagement via a mobile app and web dashboard.

2. Start-Up Capital Requirements

A. Facilities & Equipment (Fixed Assets)

Sr.	*Description*	*Qty*	*Unit Cost (PKR)*	*Total (PKR)*
1	Smart Bins (IoT, RFID, sensors)	1000	25,000	25,000,000
2	GPS Devices for Vehicles	100	10,000	1,000,000
3	Drones (AI-integrated)	10	200,000	2,000,000
4	Electric Mini Sweepers	10	1,200,000	12,000,000
5	QR Code Scanners	1000	2,000	2,000,000
6	Office Setup & Command Center	-	-	2,500,000
7	Branding & Legal	-	-	500,000

8	IT Equipment	-	-	1,000,000
	Total Fixed Assets			**46,000,000**

B. Working Capital (3 Months)

Description	Monthly (PKR)	3 Months Total
Salaries	600,000	1,800,000
Rent, Utilities, Internet	200,000	600,000
Marketing	300,000	900,000
Maintenance	100,000	300,000
		3,600,000

C. Software and Cloud Infrastructure

Description	Cost (PKR)
Mobile App	3,000,000
Admin Dashboard	2,000,000
AI Detection/Prediction	4,000,000
Cloud Tools	2,000,000
	11,000,000

D. Total Start-up Capital Required

Component	Amount (PKR)
Fixed Assets	46,000,000
Working Capital	3,600,000
Software & Cloud	11,000,000
Total	**60,600,000**

3. Sources of Finance

Source	%	Amount (PKR)
Equity (Govt. Grants)	65%	39,390,000
Debt (Loan)	35%	21,210,000
Total	100%	**60,600,000**

4. Revenue Forecast – Year 1

Metric	*Value*
Monthly Subscription per Zone	*8,000 PKR*

Target Zones	*2,500*
Annual Revenue	*240,000,000 PKR*

5. Cost of Goods Sold (COGS) – Year 1

Expense	*Estimated (PKR)*
Maintenance & Fuel	*5,000,000*
Employee Salaries	*6,000,000*
Repairs & Service	*2,000,000*
Cloud Hosting	*1,500,000*
Total COGS	*14,500,000*

6. Projected Income Statement – Year 1

Item	Amount (PKR)
Total Revenue	240,000,000
Cost of Goods Sold	14,500,000
Gross Profit	225,500,000

Operating Expenses	(6,000,000)
Net Profit Before Tax	219,500,000
Tax (15%)	**(32,925,000)**
Net Profit After Tax	**186,575,000**

7. Financial Ratios – Year 1

Ratio	Formula	Value
Gross Profit Margin	225.5M / 240M × 100	93.96%
Net Profit Margin	186.57M / 240M × 100	77.74%
Return on Equity	186.57M / 39.39M × 100	473.6%

8. Break-even Analysis

- Fixed Costs = 6,000,000 PKR
- Revenue per Unit = 8,000 PKR
- Variable Cost per Unit = 2,000 PKR
- Contribution Margin = 6,000 PKR
- Break-even Units = 6,000,000 / 6,000 = 1,000 zones
- Break-even achievable within 5 months (target: 2,500 zones/year)

9. Payback Period

- Investment: 60,600,000 PKR
- Annual Net Profit: 186,575,000 PKR
- Payback Period = 60.6M / 186.57M = ~0.32 years (~4 months)

Assets and Liabilities

Assets

Category	Details
Tangible	Smart bins, GPS devices, drones, sweepers, office setup
Software	Mobile app, admin panel, AI models
Infrastructure	Command center, IT hardware
Data	Cleanliness metrics, issue reports, insights
Human Resource	Technical & operations staff

Liabilities

Category	Details
Financial	Long-term loan repayment
Operational	Salaries, fuel, software
Regulatory	Tax compliance, legal obligations

Technical	AI model risk, hardware failure
Cybersecurity	Data breaches, server attacks

3.6. Risk Analysis

Risk Identification

A. Project Risks

Risk	Category	Summary
Scope creep	Project	Feature-rich system with AI, IoT, and citizen interfaces can lead to uncontrolled scope changes.
Schedule delays	Project	Multiple subsystems (AI, mobile app, hardware integration) increase complexity and development time.
Budget overruns	Project	High cost of AI models, smart bins, GPS tracking, CCTV analysis, and e-payment integration.

B. Technical Risks

Risk	Category	Summary
Integration failure	Technical	Interfacing AI, IoT, GPS, NADRA, e-payment, etc., may lead to incompatibility or unreliable performance.
Sensor inaccuracy	Technical	Ultrasonic sensors and drones may provide incorrect or inconsistent data.
AI misclassification	Technical	AI may incorrectly detect littering or bin fullness, reducing trust and efficiency.
Data overload	Technical	Managing large real-time data (from bins, GPS, CCTV) may overwhelm servers.

C. Business Risks

Risk	Category	Summary
User adoption risk	Business	Citizens may not use the app or report issues if the UX is poor or trust is low.
Government policy change	Business	Change in municipal policies may reduce support for integration or funding.
Vendor risk	Business	Sensor/device vendors or third-party APIs (e.g., NADRA) may become unavailable.

D. People Risks

Risk	Category	Summary
Staff turnover	People	Loss of AI/IoT experts may delay progress.
Skill mismatch	People	The team may lack expertise in real-time AI, drone footage, Urdu NLP, or e-payment APIs.

2. Risk Projection (Estimation)

Risk	Probability	Impact	Category	Overall Risk
Integration failure	High	Critical	Technical	High
Sensor inaccuracy	Medium	Marginal	Technical	Medium
AI misclassification	High	Critical	Technical	High
Schedule delay	Medium	Critical	Project	High
Budget overrun	Medium	Critical	Project	High
Government policy change	Low	Critical	Business	Medium
User adoption failure	Medium	Marginal	Business	Medium
Staff turnover	Medium	Marginal	People	Medium

3. Risk Mitigation, Monitoring & Management

Proactive Strategies

Risk	Mitigation Strategy
Integration failure	Define integration standards early. Use middleware/APIs and test interoperability in small increments.
Sensor inaccuracy	Calibrate and test sensors in real environments before deployment. Use redundancy or fallback mechanisms.
AI misclassification	Train models on local datasets. Regularly update them with new data. Allow manual override for alerts.
Schedule delay	Use agile sprints with strict milestones. Track progress weekly and apply buffer time.
Budget overrun	Allocate contingency budget. Monitor high-cost components (AI, drones) closely.
User adoption	Conduct user testing and engagement campaigns. Make app UX simple and provide incentives.
Government API changes	Establish MoUs with government bodies and prepare for local caching/fallback systems.

Staff turnover	Document all components. Cross-train team members. Maintain a knowledge base.

LOGO

Flyer Design