



## SDG BLOCKCHAIN ACCELERATOR

### Technical Architecture Document – Reloop

## 1. Project Information

- **Project Name:** RELOOP
- **Challenge & UNDP Office:** UNDP GEORGIA
- **Document Version:** VERSION 2

## 2. Overview

RELOOP is a decentralized e-waste recycling incentive platform built on Cardano using Aiken smart contracts. The system gamifies electronic waste disposal by providing ADA rewards to users who properly recycle their electronic devices at designated collection bins, directly supporting **SDG 12: Responsible Consumption and Production** and **SDG 11: Sustainable Cities and Communities**.

### Problem Statement

Electronic waste (e-waste) is the world's fastest-growing waste stream, with only 20% being formally recycled globally. Key challenges include:

- **Lack of Incentives:** No immediate rewards for proper e-waste disposal
- **Limited Accessibility:** Difficulty finding convenient recycling locations
- **Poor Tracking:** No transparent system to verify recycling impact
- **Informal Recycling:** Unsafe practices in developing countries
- **Consumer Apathy:** Low awareness of e-waste environmental impact

## 3. System Architecture Diagram

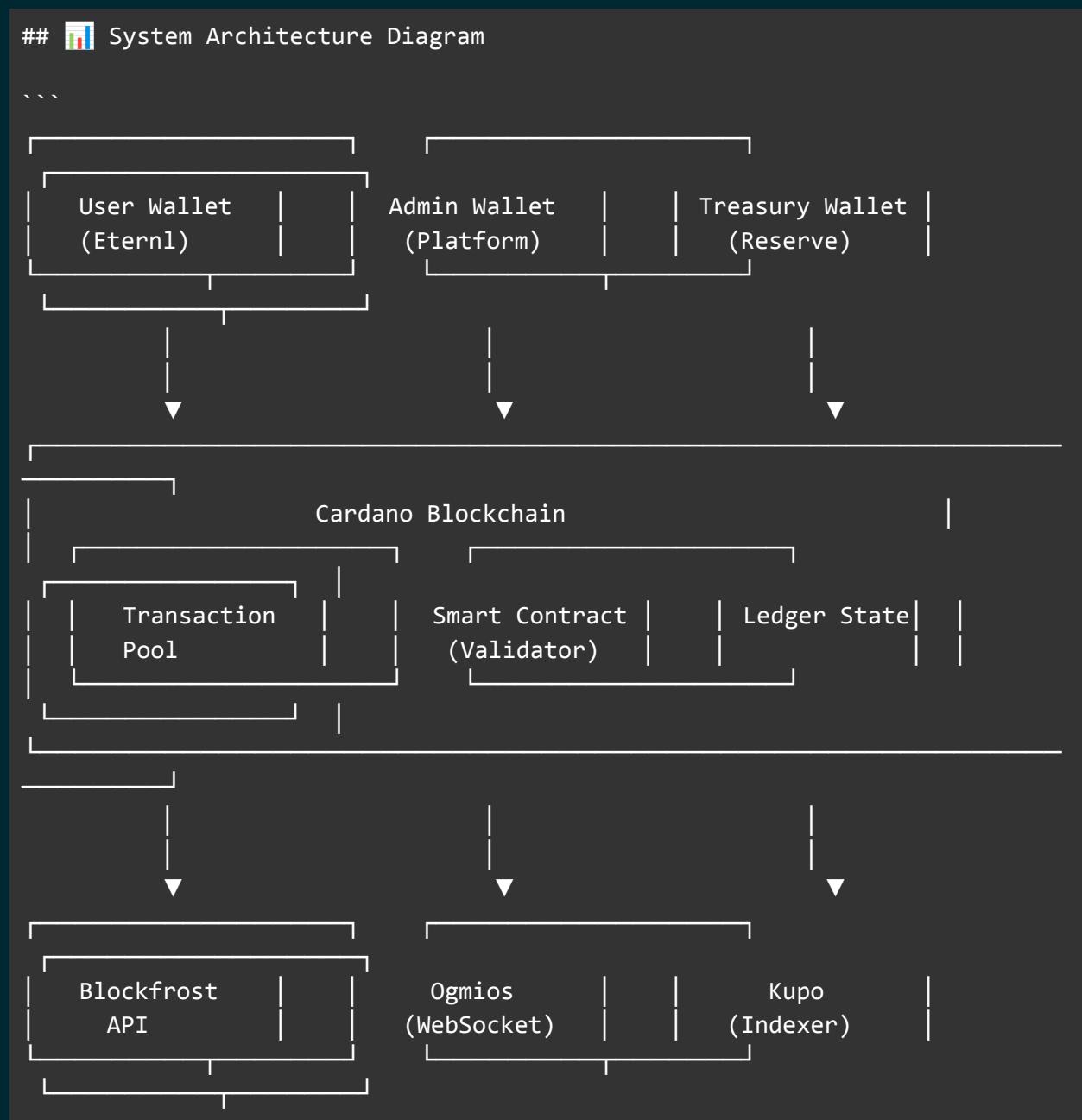
*(Insert a diagram showing components, interactions, and data flow. Can be drawn in any tool and attached.)*

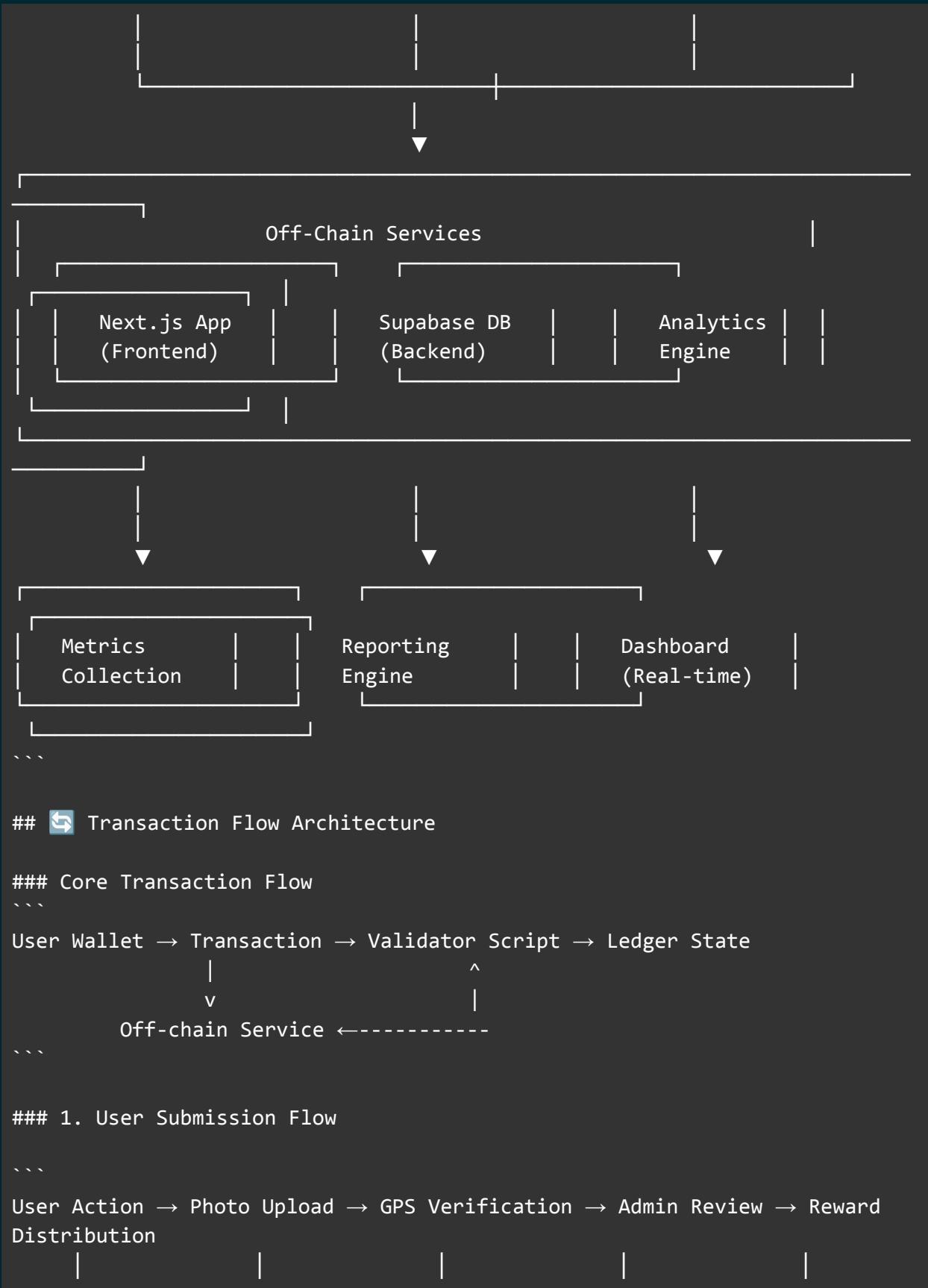
### Components to include:

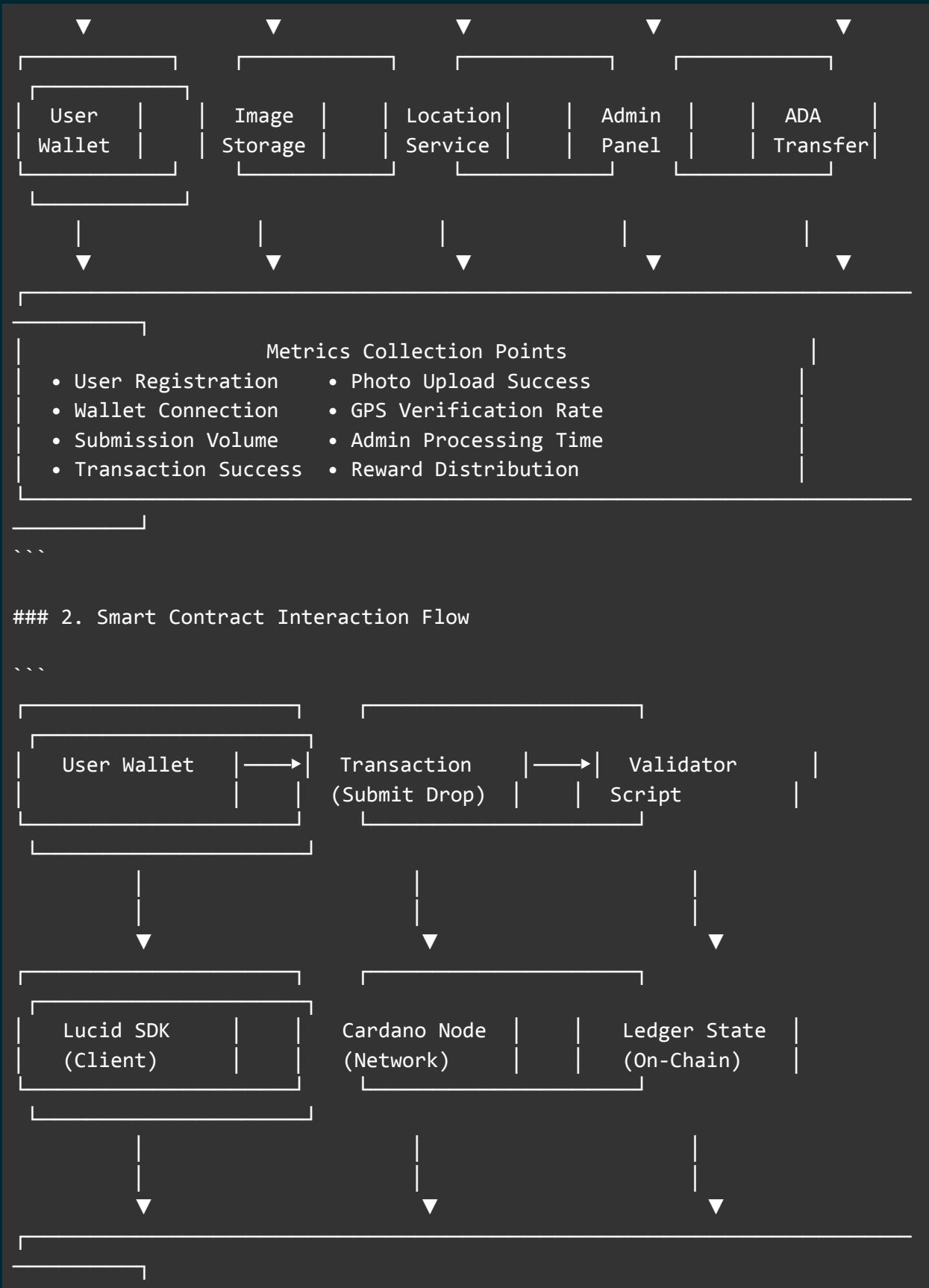
- User Wallets

- Aiken Validator Scripts
- Off-chain components (backend services, PAB alternative, dashboards)
- Cardano Ledger (UTxO)
- Oracles / external data sources (if any)

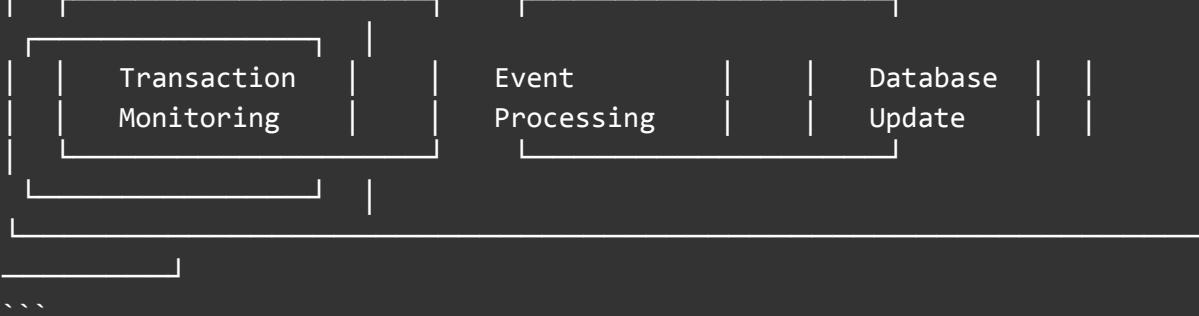
**Example (ASCII for illustration):**







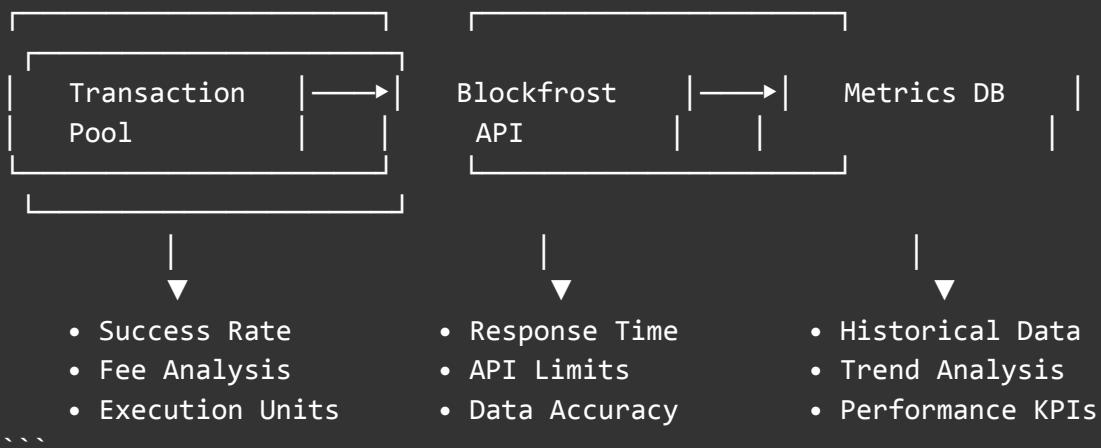
## Off-Chain Service Layer



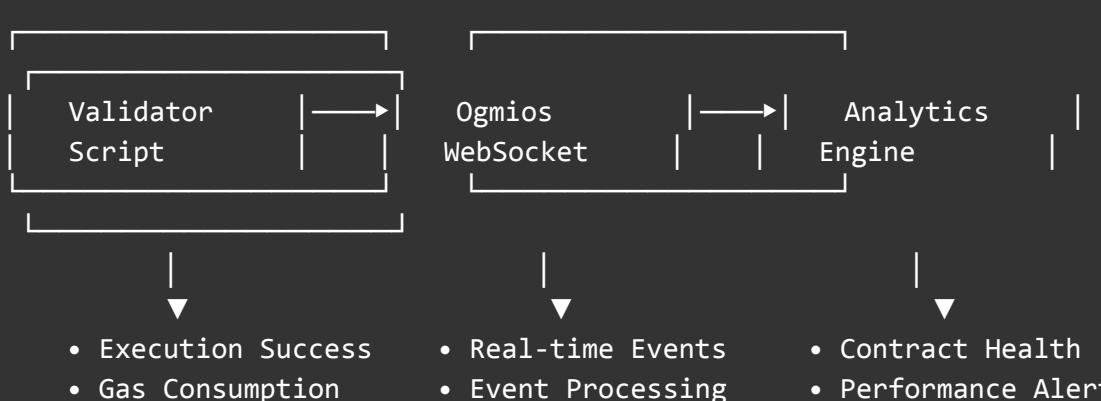
## ## 📈 Metrics Collection Architecture

### ### Blockchain Layer Metrics

#### #### Transaction Monitoring



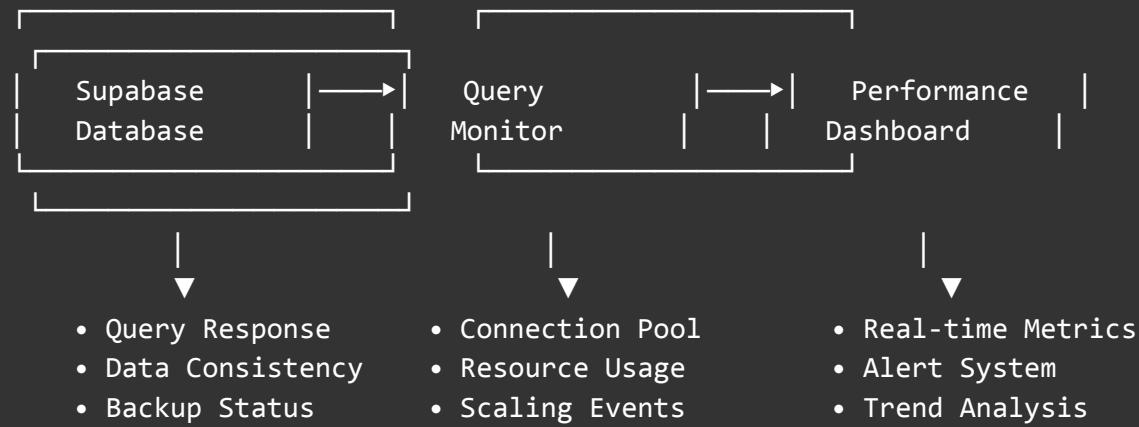
#### #### Smart Contract Metrics



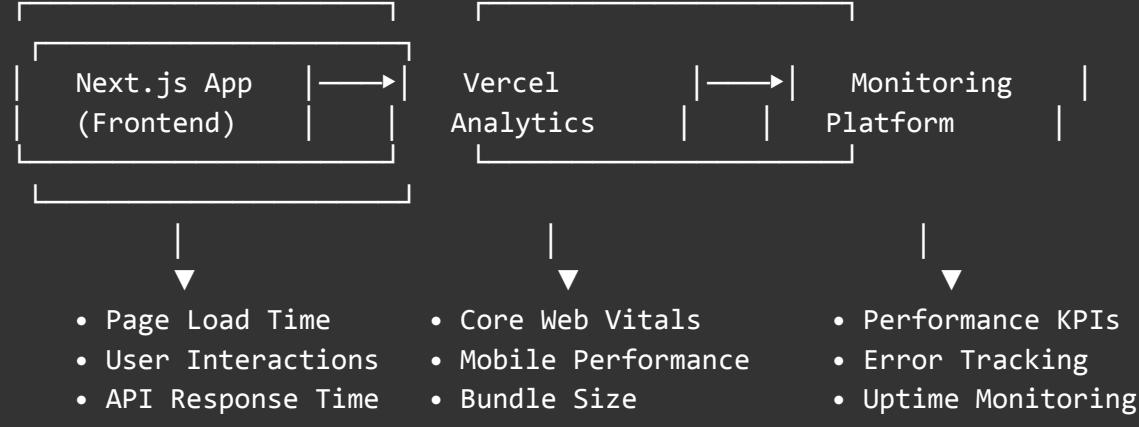
- Validation Logic
- Data Consistency
- Error Tracking

### ### Off-Chain Service Metrics

#### #### Database Performance



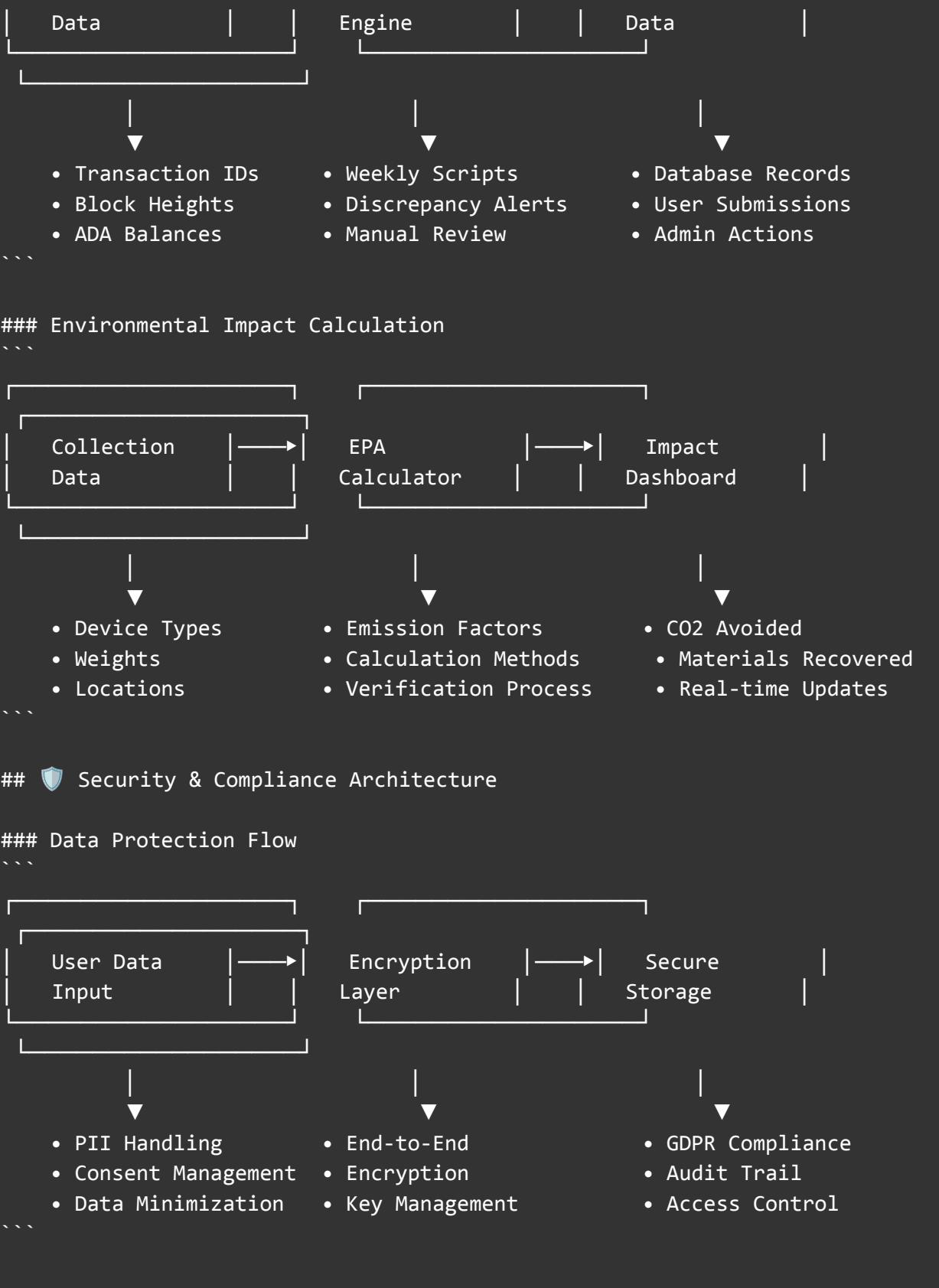
#### #### Application Performance



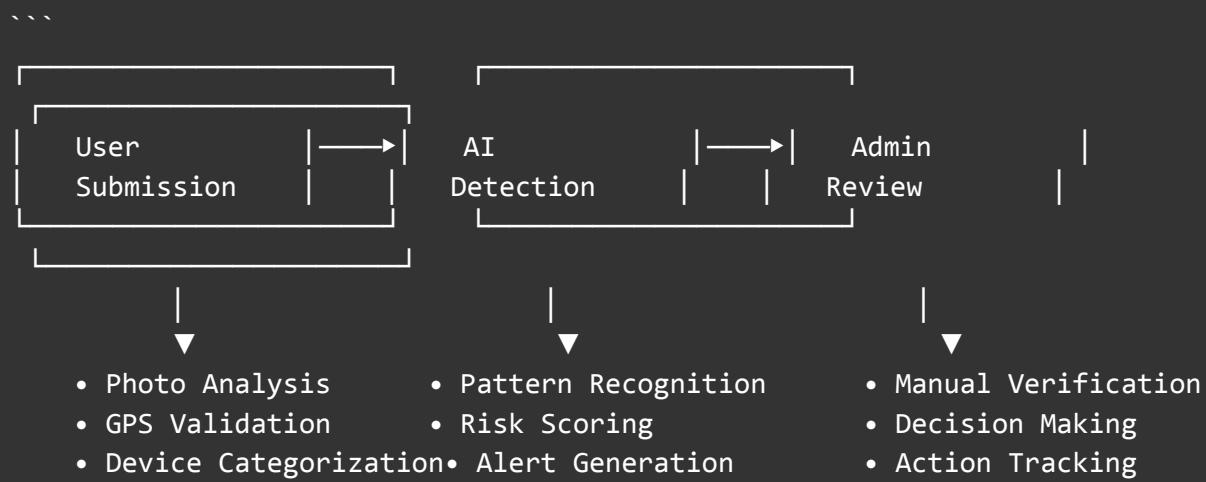
## ## 🔎 Data Validation & Reconciliation

### ### Cross-System Verification



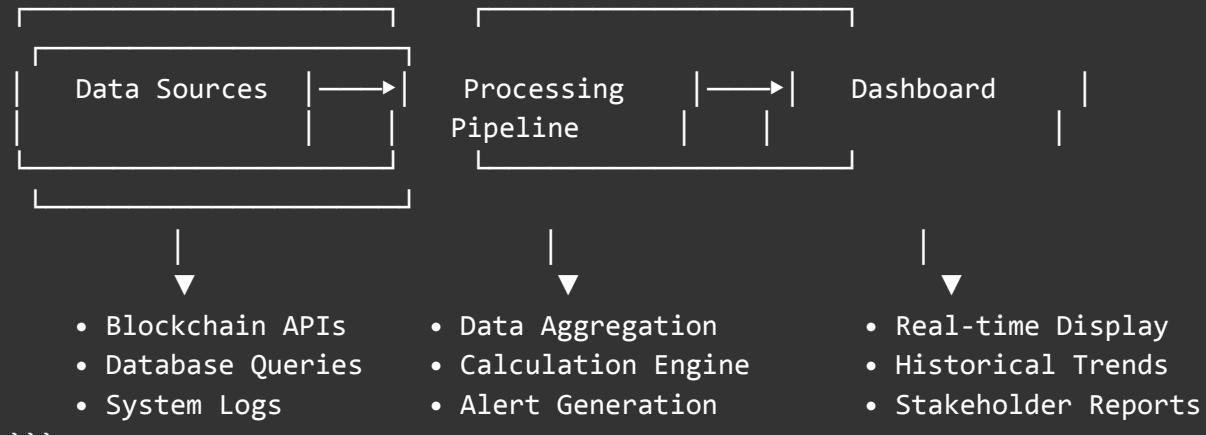


### ### Fraud Detection Flow

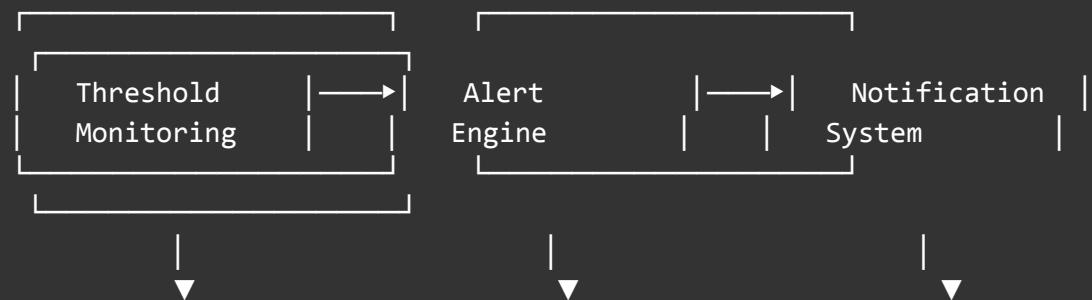


## ## 📊 Real-Time Monitoring Architecture

### ### Metrics Pipeline



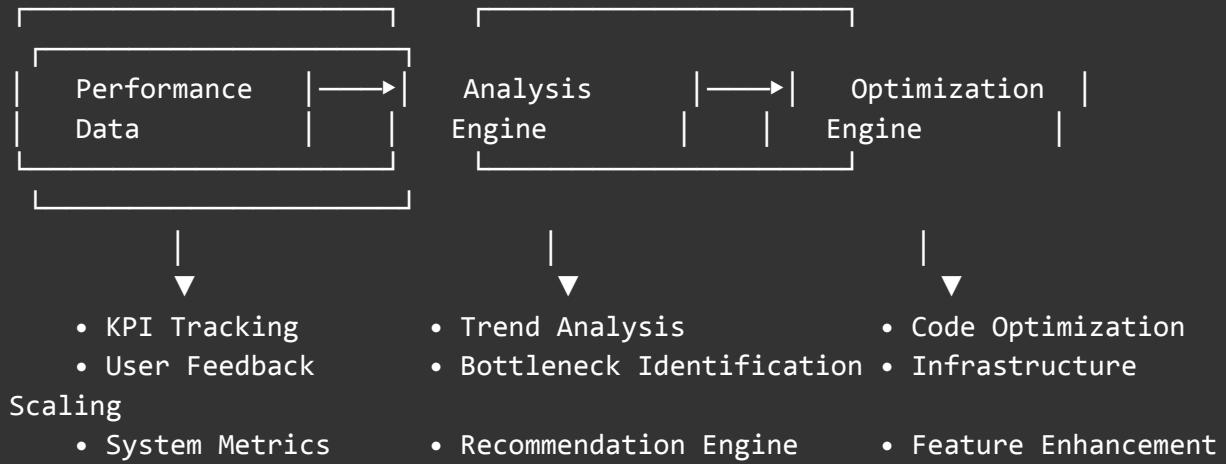
### ### Alert System



- Performance KPIs
- Error Rates
- System Health
- Rule Evaluation
- Severity Assessment
- Action Triggers
- Email/Slack
- Escalation Matrix
- Response Tracking

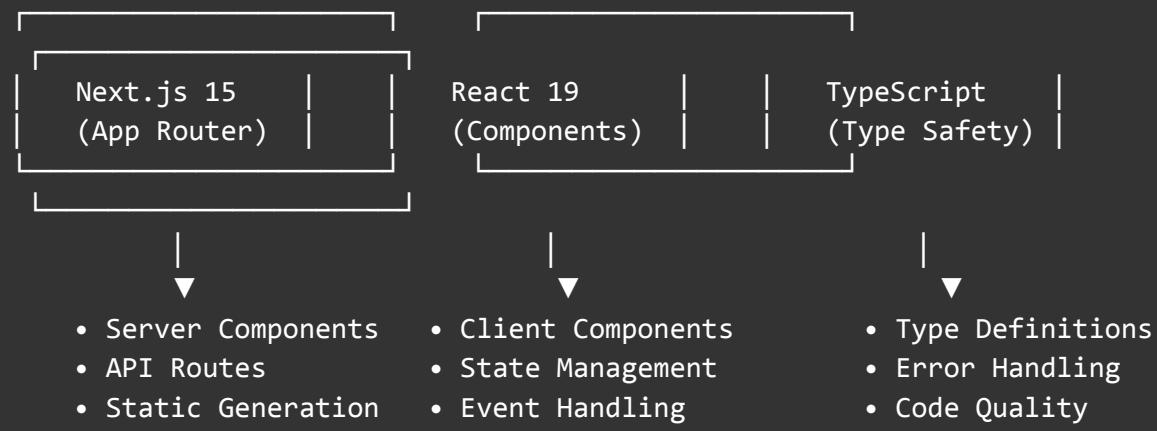
## ## 🔍 Continuous Improvement Architecture

### ### Feedback Integration Loop

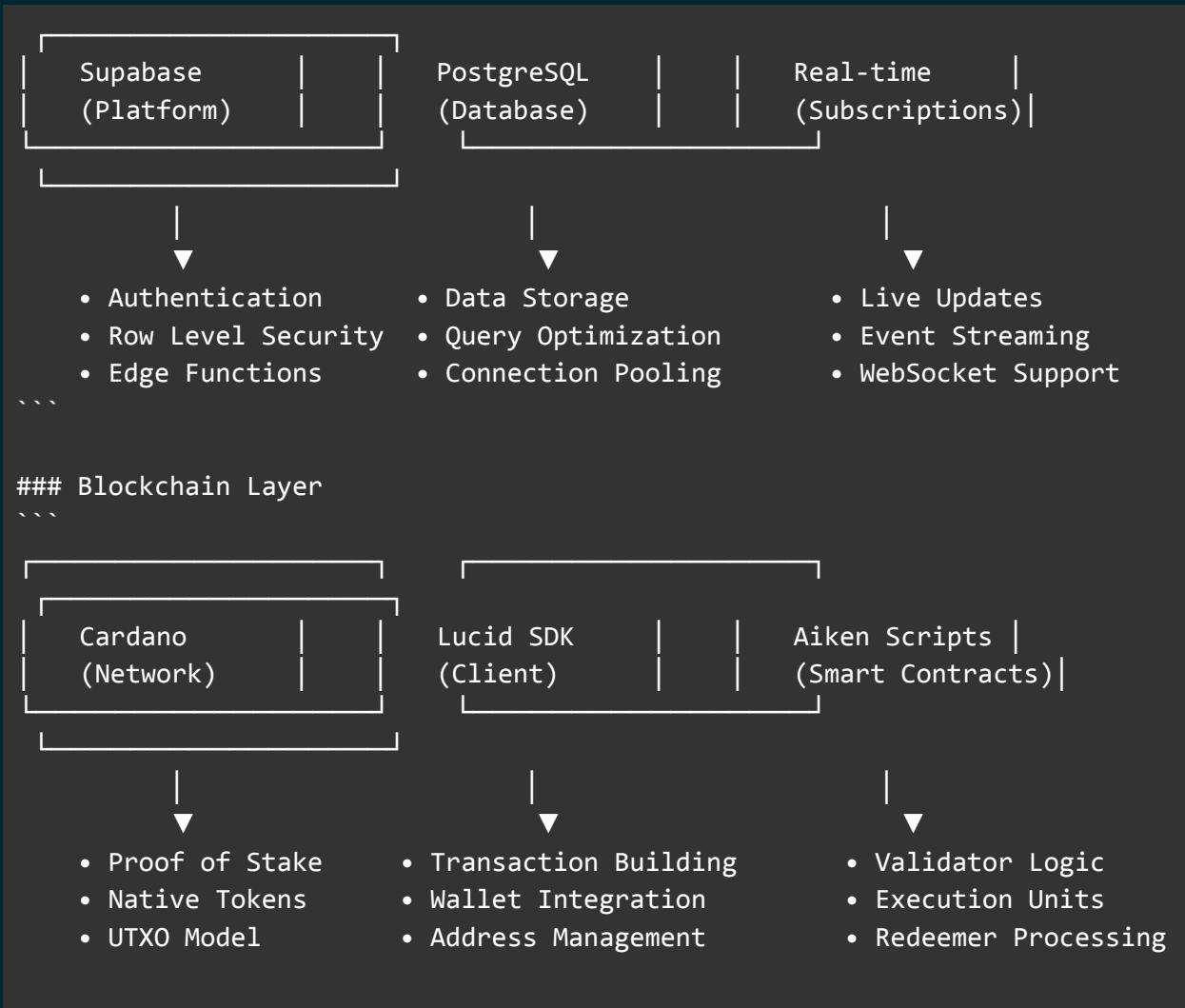


## ## 🛠️ Technology Stack Architecture

### ### Frontend Layer



### ### Backend Layer



## 4. Blockchain Design

**Authorization Control:** Users can only claim their own rewards, admins control bin management

**Data Integrity:** All inputs validated for type, format, and business rules

**Replay Protection:** Unique IDs and state flags prevent duplicate transactions

**Overflow Protection:** Mathematical operations checked for underflow/overflow

**Location Verification:** GPS coordinates validated for proximity and authenticity

**Time Window Validation:** Timestamps must be within acceptable range

**Batch Size Limits:** Maximum 50 users per batch to prevent transaction size issues

**UTxO State Consistency:** Proper input consumption and output creation patterns

## Treasury Management

- **Initial Funding:** Treasury UTxO pre-loaded with ADA reward pool
- **Replenishment:** Admin can add funds to treasury via separate transactions
- **Balance Tracking:** Off-chain monitoring ensures sufficient funds for payouts
- **Reserve Requirements:** Minimum balance maintained for operational continuity

#### **Ownership Tracking via Datum**

- **Individual Ownership:** Each user's consolidated wallet linked to user\_id
- **Balance Accumulation:** individual\_balance tracks pending rewards per user
- **Historical Records:** total\_earned provides lifetime earning transparency
- **Audit Trail:** All drops linked to specific users and timestamps

#### **Validator Script: reloop\_treasury**

**Purpose:** Single comprehensive validator managing all e-waste recycling operations including drop submissions, reward claims, wallet management, bin registry, and batch processing.

#### **Core Functions:**

- **Access Control:** Validates user permissions for different actions
- **State Management:** Handles UTxO state transitions for all datum types
- **Reward Distribution:** Manages ADA rewards from treasury to users
- **Data Integrity:** Ensures proper datum structure and validation rules
- **Smart Contracts:**
  - Validator script(s) with purpose (e.g., minting policy, access control)
  - Datum structure (metadata, user ID, token info)
  - Redeemer structure (actions: mint, burn, transfer)
- **UTxO Model Usage:**
  - How inputs and outputs are handled
  - Examples of typical transaction flows
- **Token Management:**
  - On-chain asset minting/burning rules
  - Tracking ownership via datum
- **Security Considerations:**

- Signature checks (authorized wallets)
- Datum/redeemer validation
- Replay protection / double-spend prevention

## 5. Data Flow & Transaction Lifecycle

### **Step 1: User Initiates Drop**

1. *User opens RELOOP mobile app at recycling bin location*
2. *App scans QR code on bin to identify bin\_id and location*
3. *User selects device type from predefined list (smartphone, laptop, battery, etc.)*
4. *App captures photo of e-waste item being deposited*
5. *App automatically captures GPS coordinates of user's current location*
  - o *Creates DropDatum structure with all required fields*

## 6. Off-chain Components

### **Step 2: Off-chain Validation & Processing**

6. **Photo Service** receives image and generates SHA-256 hash
  - o *Original photo stored on IPFS for proof-of-disposal*
  - o *Hash included in transaction for on-chain verification*
7. **GPS Oracle** validates location data
  - o *Confirms user is within 1km radius of specified bin*
  - o *Validates GPS coordinates are within valid ranges (-90° to 90° lat, -180° to 180° long)*
  - o *Cross-references bin location from database*
8. **API Gateway** aggregates validated data

- o Combines photo hash, GPS coordinates, device type, timestamps
- o Calculates reward amount based on device type

## 7. Sandbox/Testnet Results

**Example:**

Transaction ID	Type	Status	CPU	Memory	Notes
`abc123def456`	Mint	Success	310K	900k	Validator passed all checks
def456ghi789`	Transfer	Success	280k	850k	Tested edge case: invalid redeemer
`ghi789jkl012`	Submit Drop	Success	295K	875k	Photo upload + GPS verification
`mno345pqr678`	Register Wallet	Success	245K	750k	New user registration
`stu901vwx234`	Update Treasury	Success	275K	825k	Treasury balance update
`vwx234yza567`	Validate Location	Success	290K	880k	GPS verification test
`jkl012mno345`	Claim Reward	Success	265K	800k	Batch processing test

## 9. Tools and Environments Used

*aiken v1.1.17+c3a7fba*

*aiken check - Static analysis and type checking*

*aiken build - Contract compilation*

*aiken test - Unit test execution with coverage reports*

*aiken fmt - Code formatting and style consistency*

- 🎬 **Cardano Emulator:** Local blockchain simulation using Aiken's built-in testing framework
- 🎬 **Transaction Simulation:** Full transaction lifecycle testing from submission to confirmation
- 🎬 **Multi-UTxO Scenarios:** Testing complex scenarios involving multiple inputs/outputs

## 10. Remaining Considerations / Next Steps

### Pending Architecture Changes & Improvements

#### Smart Contract Optimizations

- **Validator Script Improvements:** High priority - reduce memory usage by 15-20%
- **Execution Unit Optimization:** Medium priority - reduce average execution units by 10-15%
- **Target:** <250,000 execution units and <800KB memory usage

#### Infrastructure Improvements

- **Database Performance:** Query response time reduction by 20-30% (target: <60ms)
- **API Response Time:** Response time reduction by 15-20% (target: <150ms)
- **Implementations:** Redis caching, database indexes, CDN, read replicas
- 

#### Security Enhancements

- **Multi-Signature Wallet:** High priority - enhance treasury security
- **Advanced Fraud Detection:** Medium priority - improve accuracy by 5-8%
- **Target:** >98% fraud detection accuracy

### Pre-Production Deployment Plan

#### Cardano Preprod Testing Phase

- **Duration:** 30 days starting January 15, 2025
- **Objectives:** Validate mainnet performance under high load
- **Stress Testing:** 1,000 concurrent users, 1,000 transactions/minute

- **Target Metrics:** >99.5% success rate, <250,000 execution units, <800KB memory

#### **Security Audit Roadmap**

##### **Three-Phase Security Audit**

1. **Phase 1 (January 2025):** Smart contract security audit by third-party firm
2. **Phase 2 (February 2025):** Application security audit by cybersecurity firm
3. **Phase 3 (March 2025):** Operational security audit by internal + external team

#### **Continuous Improvement Plan**

##### **Regular Review Cycles**

**Monthly Performance Reviews:** First Monday of each month

**Quarterly Architecture Reviews:** March, June, September, December

**Annual Security Assessment:** December 2025