

Railway Safety Metrics Module

Comprehensive System Architecture & Implementation Guide

RailSync Pro - Safety Enhancement Platform

MODULE OVERVIEW

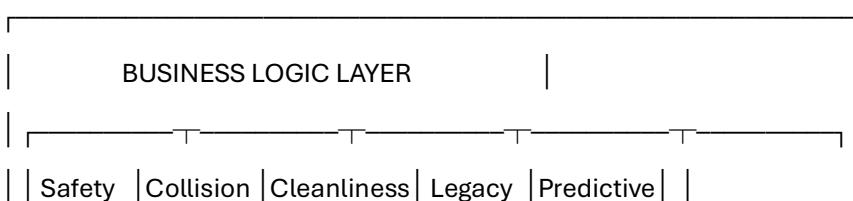
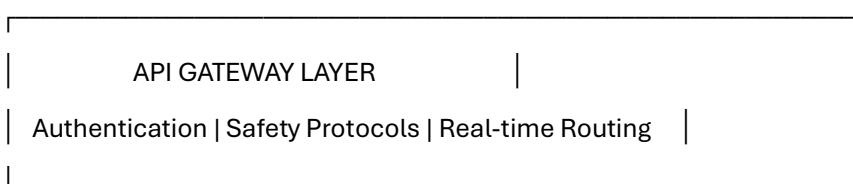
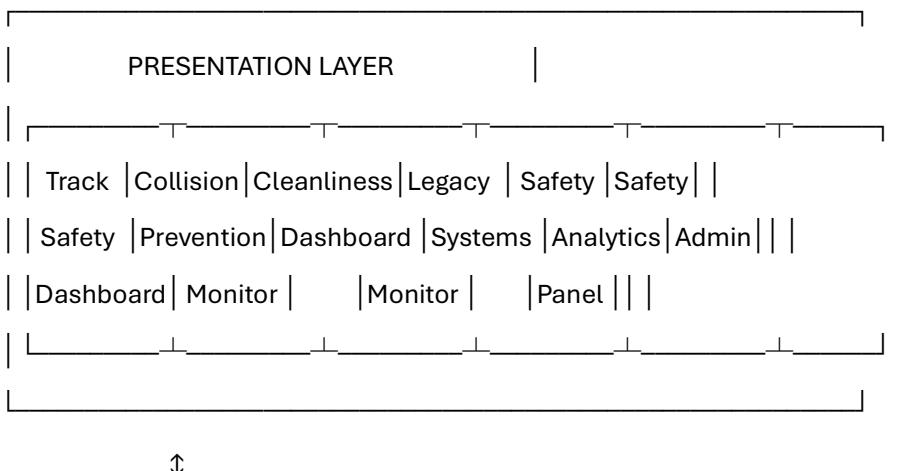
Module Name: SafetySync - Integrated Railway Safety Metrics Platform

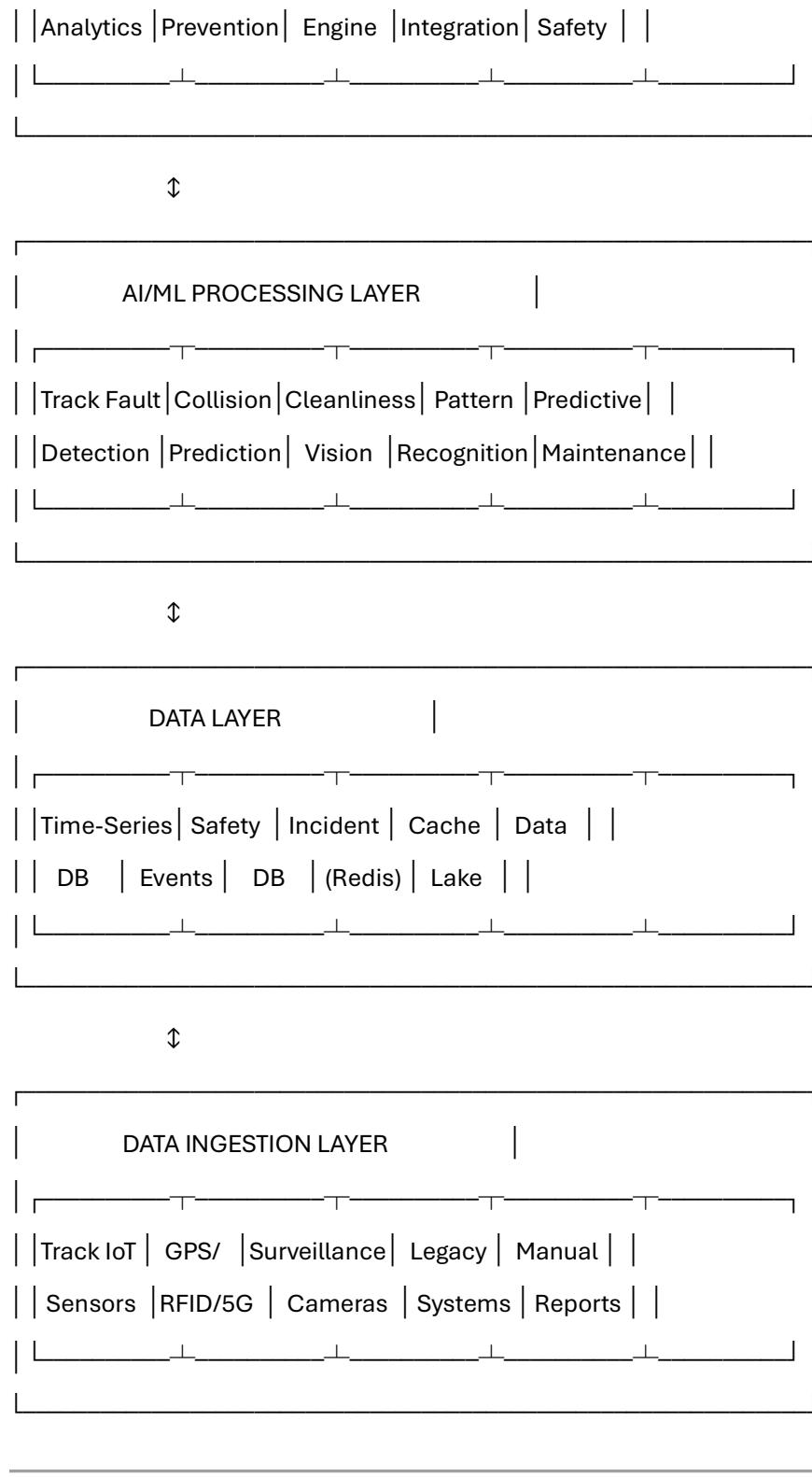
Core Philosophy

Transform Indian Railways' safety infrastructure through real-time monitoring, predictive analytics, and AI-powered collision prevention systems. This module integrates historical safety systems (AWS, TPWS, ACD) with modern IoT-based solutions to create a comprehensive safety ecosystem.

SAFETY METRICS ARCHITECTURE

1. HIGH-LEVEL SAFETY ARCHITECTURE





DETAILED SAFETY MODULE BREAKDOWN

MODULE 1: TRACK SAFETY MONITORING

1.1 Track Condition Monitoring

Data Sources:

- Ultrasonic rail flaw detectors
- Track geometry cars
- Vibration sensors
- Temperature sensors
- Rail stress monitors
- Accelerometers on trains
- Visual inspection cameras

Data Structure:

```
{  
  "trackSafety": {  
    "timestamp": "ISO8601",  
    "sectionId": "string",  
    "location": {  
      "sectionCode": "string (e.g., DLI-NDLS-SEC-5)",  
      "kilometerPost": "float",  
      "latitude": "float",  
      "longitude": "float",  
      "trackNumber": "int (1/2/3)",  
      "zone": "string (North/South/East/West/Central)"  
    },  
    "geometryMetrics": {  
      "gauge": "float (mm, standard: 1676mm)",  
      "gaugeDeviation": "float (mm)",  
      "crossLevel": "float (mm)",  
      "alignment": "float (mm)",  
      "surfaceIrregularity": "float (mm)",  
      "cant": "float (mm)",  
      "cantDeficiency": "float (mm)",  
      "twist": "float (mm/m)"  
    },  
  },  
}
```

```
"railCondition": {  
    "railProfile": "string (wear_level: normal/moderate/severe)",  
    "weldQuality": "float (0-100 score)",  
    "surfaceDefects": "array",  
    "crackDetected": "boolean",  
    "crackLength": "float (mm)",  
    "crackDepth": "float (mm)",  
    "corrosionLevel": "string (none/mild/moderate/severe)",  
    "fatigueIndex": "float (0-100)"  
},  
"structuralHealth": {  
    "sleeperCondition": "string (good/fair/poor/critical)",  
    "ballastCondition": "string (good/settled/fouled/missing)",  
    "fastenersLoose": "int (count)",  
    "railTemperature": "float (°C)",  
    "thermalStress": "float (MPa)",  
    "bridgeStructure": "object (if applicable)"  
},  
"environmentalFactors": {  
    "weatherCondition": "string (clear/rain/fog/snow)",  
    "groundwater": "float (mm)",  
    "soilMoisture": "float (%)",  
    "ambientTemperature": "float (°C)",  
    "windSpeed": "float (km/h)"  
},  
"riskAssessment": {  
    "overallRiskScore": "float (0-100)",  
    "riskCategory": "string (low/moderate/high/critical)",  
    "failureProbability": "float (0-1)",  
    "timeToFailure": "float (days)",  
    "maintenancePriority": "string (routine/urgent/emergency)"  
}
```

```

    "speedRestrictionRequired": "boolean",
    "recommendedSpeed": "float (km/h)"
},
"alerts": [
{
    "alertId": "string",
    "alertType": "string (track_fault/geometry_deviation/crack_detected)",
    "severity": "string (low/medium/high/critical)",
    "description": "string",
    "actionRequired": "string",
    "escalationLevel": "int (1-4)",
    "assignedTo": "string"
}
]
}
}

```

AI/ML Algorithms:

1. Track Fault Detection: Deep Learning CNN

- Architecture: ResNet-50 modified for track defect classification
- Input: High-resolution track images
- Output: Defect type, location, severity
- Accuracy target: >95%

2. Crack Propagation Prediction: Physics-Informed Neural Network (PINN)

- Combines physics-based models with neural networks
- Predicts crack growth rate
- Estimates remaining safe operational time

3. Geometry Deviation Detection: Statistical Process Control + LSTM

- Monitors track geometry parameters
- Detects trends and anomalies
- Forecasts future deviations

4. Maintenance Scheduling: Multi-Objective Optimization

- Algorithm: NSGA-III (Non-dominated Sorting Genetic Algorithm)
- Objectives: Minimize risk, minimize cost, maximize track availability
- Constraints: Resource availability, weather windows

5. Risk Scoring: Ensemble Model

- Combines: Random Forest + Gradient Boosting + Neural Network
- Features: Historical failures, current condition, environmental factors
- Output: Probabilistic risk assessment

Visualizations:

- Real-time track condition heatmap (geographic view)
 - Track geometry trend charts
 - Risk distribution histogram
 - Maintenance priority matrix
 - Defect type distribution pie chart
 - Predictive failure timeline
 - Speed restriction zones map
-

1.2 Signal System Safety

Data Sources:

- Signal aspect sensors
- Point machine sensors
- Track circuit monitors
- Axle counter systems
- Interlocking system logs

Data Structure:

```
{
  "signalSafety": {
    "timestamp": "ISO8601",
    "signalId": "string",
    "location": {
      "stationCode": "string",
      "signalNumber": "string",
    }
  }
}
```

```
"kilometerPost": "float",
"coordinates": {"lat": "float", "lon": "float"}
},
"signalStatus": {
"currentAspect": "string (red/yellow/double_yellow/green)",
"intendedAspect": "string",
"aspectAgreement": "boolean",
"lampFailure": "boolean",
"visibilityIndex": "float (0-100)",
"powerSupplyStatus": "string (normal/backup/failure)"
},
"trackCircuit": {
"occupied": "boolean",
"trackCircuitCurrent": "float (mA)",
"trackCircuitVoltage": "float (V)",
"bondResistance": "float (ohms)",
"shortCircuitDetected": "boolean",
"trackCircuitHealth": "string (healthy/degraded/failed)"
},
"pointMachine": {
"pointPosition": "string (normal/reverse)",
"lockedPosition": "boolean",
"detectionStatus": "string (in_position/in_transit/failed)",
"operationTime": "float (seconds)",
"forceRequired": "float (Newtons)",
"motorCurrent": "float (Amperes)",
"switchBladesContact": "boolean"
},
"interlocking": {
"routeSet": "string",
"conflictingRoutes": "array",
```

```

"safetyChecksPass": "boolean",
"timeLockStatus": "string (locked/unlocked)",
"approachLockingActive": "boolean"
},
"anomalies": {
  "wrongSideFailure": "boolean",
  "aspectSequenceViolation": "boolean",
  "unauthorizedAspectChange": "boolean",
  "signalPassedAtDanger": "boolean (SPAD)",
  "predictedFailure": "float (probability 0-1)"
}
}
}

```

AI/ML Algorithms:

1. **Signal Failure Prediction: Survival Analysis**
 - o Algorithm: Cox Proportional Hazards Model
 - o Predicts time to next failure
 - o Identifies high-risk components
2. **SPAD (Signal Passed At Danger) Risk Assessment: Classification**
 - o Algorithm: XGBoost Classifier
 - o Features: Signal visibility, train speed, driver behavior history
 - o Output: SPAD risk score per signal
3. **Interlocking Anomaly Detection: Sequence Analysis**
 - o Algorithm: Hidden Markov Model (HMM)
 - o Detects unusual state transitions
 - o Identifies potential safety violations

MODULE 2: COLLISION PREVENTION SYSTEMS

2.1 Legacy System Integration

Historical Systems Overview:

A. Auxiliary Warning System (AWS)

- **Technology:** Track magnets + onboard receivers
- **Coverage:** Primarily Mumbai suburban network
- **Limitations:**
 - Limited data capacity (binary: stop/proceed)
 - Prone to theft of track magnets
 - No continuous speed monitoring
 - No train-to-train communication

B. Train Protection and Warning System (TPWS)

- **Technology:** Based on ETCS Level 1
- **Components:** Track-mounted transponders + onboard equipment
- **Limitations:**
 - High cost: ₹15-20 lakhs per kilometer
 - Extensive cabling requirements
 - Not scalable for 68,000 km network
 - Weather-dependent performance

C. Anti-Collision Device (ACD)

- **Developer:** Konkan Railway + Kernenex (2000s)
- **Technology:** GPS + Radio communication
- **Limitations:**
 - Lacked SIL-4 (Safety Integrity Level 4) certification
 - GPS accuracy issues in tunnels/dense areas
 - Radio interference problems
 - Not fail-safe compliant

2.2 Modern Collision Prevention Architecture

Data Sources:

- GPS/GNSS receivers (multi-constellation)
- 5G/LTE communication modules
- RFID track markers
- Onboard radar systems
- Train-to-Train communication (V2V)
- Train-to-Infrastructure communication (V2I)

- Balise readers
- Doppler radar speedometers

Data Structure:

```
{
  "collisionPrevention": {
    "timestamp": "ISO8601",
    "trainId": "string",
    "location": {
      "latitude": "float (high precision: ±0.5m)",
      "longitude": "float",
      "altitude": "float",
      "accuracy": "float (meters)",
      "positioningMethod": "string (GPS/RFID/Balise/Hybrid)",
      "kilometerPost": "float",
      "trackId": "string",
      "blockSection": "string"
    },
    "dynamics": {
      "currentSpeed": "float (km/h)",
      "acceleration": "float (m/s²)",
      "heading": "float (degrees)",
      "gradient": "float (%)",
      "curve": "float (radius in meters)"
    },
    "proximityData": {
      "nearbyTrains": [
        {
          "trainId": "string",
          "relativeDistance": "float (meters)",
          "relativeSpeed": "float (km/h)",
          "bearing": "float (degrees)"
        }
      ]
    }
  }
}
```

```
        "collisionRisk": "float (0-1)",  
        "timeToCollision": "float (seconds)",  
        "closingRate": "float (m/s)"  
    }  
],  
    "obstaclesDetected": "array",  
    "signalAhead": {  
        "signalId": "string",  
        "aspect": "string",  
        "distance": "float (meters)",  
        "requiredSpeed": "float (km/h)"  
    }  
,  
    "systemStatus": {  
        "awsStatus": "string (active/inactive/fault)",  
        "tpwsStatus": "string (active/inactive/fault)",  
        "acdStatus": "string (active/inactive/fault)",  
        "kavachStatus": "string (active/inactive/fault)",  
        "gpsQuality": "float (0-100)",  
        "communicationQuality": "float (0-100)",  
        "backupSystems": "array",  
        "failSafeMode": "boolean"  
    },  
    "safetyActions": {  
        "automaticBrakeApplied": "boolean",  
        "warningIssued": "boolean",  
        "speedRestrictionActive": "boolean",  
        "emergencyStop": "boolean",  
        "alertsSent": "array",  
        "loggedEvents": "array"  
    },  
}
```

```

"predictiveAnalysis": {

    "collisionProbability": "float (0-1)",

    "safeStoppingDistance": "float (meters)",

    "currentStoppingDistance": "float (meters)",

    "safetyMargin": "float (meters)",

    "actionRequired": "string (none/warning/brake/emergency)",

    "recommendedSpeed": "float (km/h)"

}

}

}

```

AI/ML Algorithms:

1. Collision Risk Prediction: Deep Reinforcement Learning

- Algorithm: Deep Q-Network (DQN) with experience replay
- State space: Train positions, speeds, track layout, signal aspects
- Action space: Maintain speed, reduce speed, apply brake, emergency stop
- Reward function: Penalize collisions, reward safe operation
- Training: Simulation environment + historical incident data

2. Position Fusion: Extended Kalman Filter (EKF)

- Fuses data from: GPS, RFID, balises, odometry
- Handles sensor noise and GPS dropouts
- Provides high-accuracy position ($\pm 0.5\text{m}$)

3. Anomaly Detection in Train Behavior: One-Class SVM

- Detects unusual acceleration patterns
- Identifies potential brake failures
- Flags erratic driver behavior

4. Communication Network Optimization: Graph Neural Network

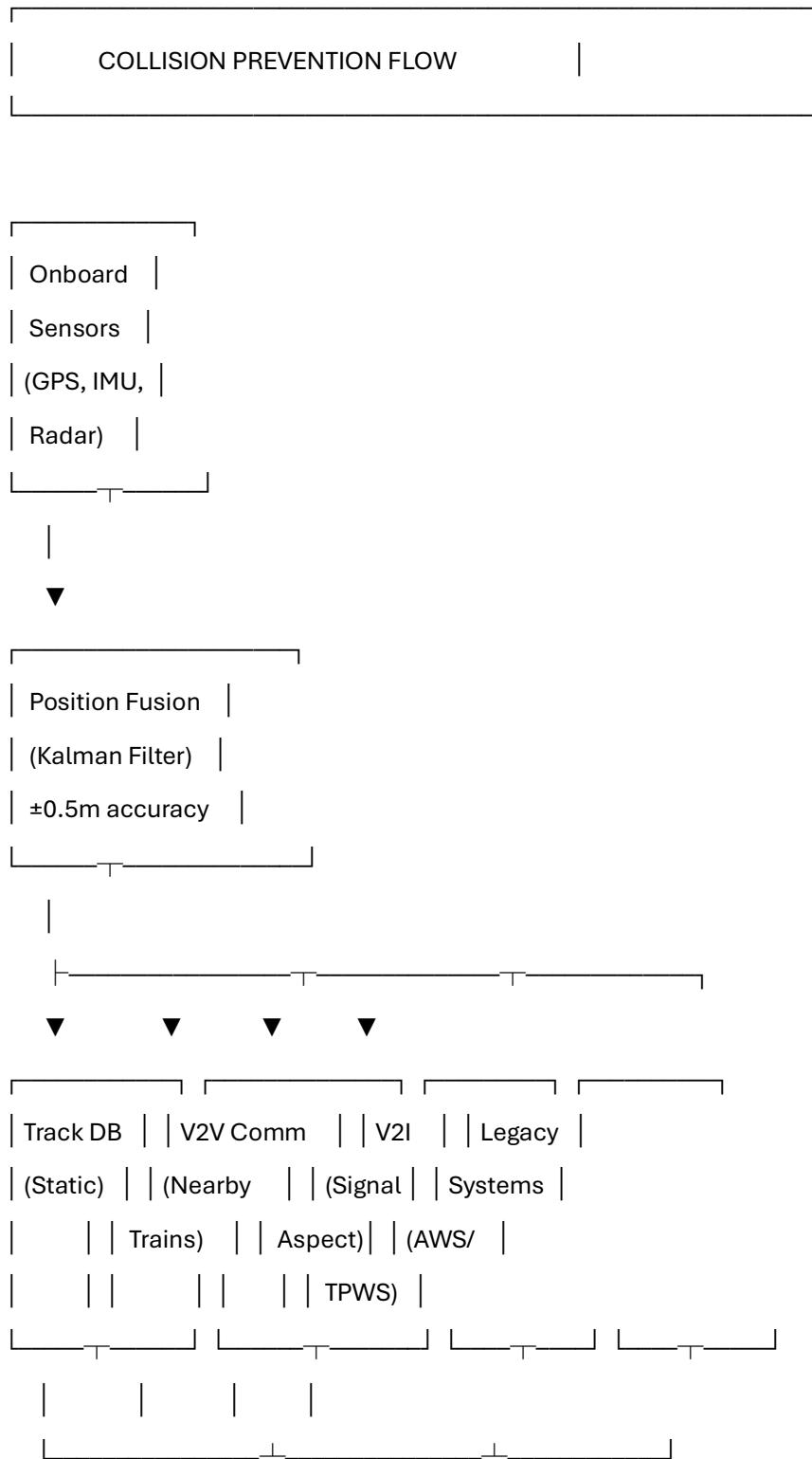
- Optimizes V2V and V2I communication routes
- Ensures redundancy in critical sections
- Predicts network congestion

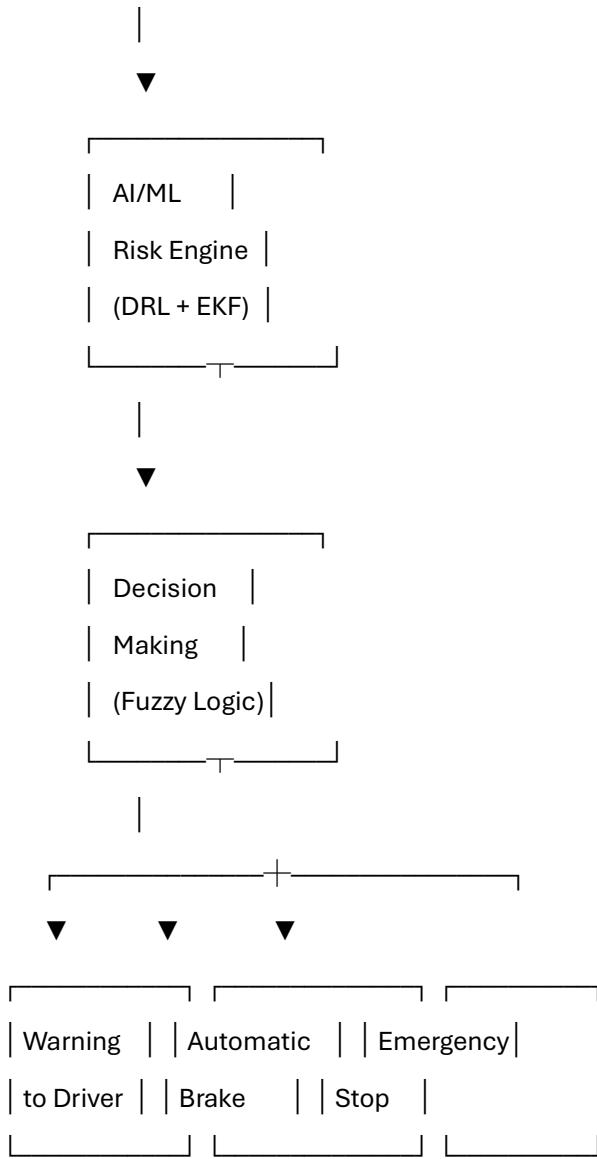
5. Fail-Safe Decision Making: Fuzzy Logic Controller

- Input variables: Distance to hazard, closing speed, brake response time

- Output: Brake force application
- Ensures SIL-4 compliance

System Integration Flow:





Visualizations:

- Real-time train position map with proximity circles
- Collision risk heatmap (geographic)
- System health dashboard (AWS/TPWS/ACD/Kavach status)
- Communication network topology
- Near-miss event timeline
- Fail-safe activation log
- Safety margin gauge

MODULE 3: CLEANLINESS MONITORING

3.1 Station & Train Cleanliness

Data Sources:

- Surveillance cameras with AI vision
- IoT cleanliness sensors
- Manual inspection reports
- Passenger feedback (mobile app)
- QR code-based spot checks
- Air quality monitors
- Waste bin level sensors

Data Structure:

```
{  
  "cleanlinessMetrics": {  
    "timestamp": "ISO8601",  
    "location": {  
      "type": "string (station/train/platform/toilet)",  
      "stationCode": "string",  
      "platformNumber": "string",  
      "trainNumber": "string",  
      "coachNumber": "string",  
      "specificArea": "string (waiting_hall/toilet/track/food_court)"  
    },  
    "visualInspection": {  
      "overallCleanlinessScore": "float (0-100)",  
      "floorCleanliness": "float (0-100)",  
      "wallsCleanliness": "float (0-100)",  
      "ceilingCleanliness": "float (0-100)",  
      "toiletHygiene": "float (0-100)",  
      "litterDetected": "boolean",  
      "litterCount": "int",  
      "litterTypes": "array (plastic/paper/food_waste/other)",  
      "graffitiDetected": "boolean",  
    }  
  }  
}
```

```
"stainsDetected": "boolean",
"pestActivity": "boolean"
},
"sensorData": {
  "airQualityIndex": "float (0-500)",
  "co2Level": "float (ppm)",
  "particulateMatter": {
    "pm2_5": "float ( $\mu\text{g}/\text{m}^3$ )",
    "pm10": "float ( $\mu\text{g}/\text{m}^3$ )"
  },
  "odorLevel": "float (0-100)",
  "humidity": "float (%)",
  "temperature": "float ( $^{\circ}\text{C}$ )",
  "wasteBinFillLevel": "float (%)",
  "soapDispenser": "float (% full)",
  "waterAvailability": "boolean"
},
"maintenanceLog": {
  "lastCleaned": "ISO8601",
  "cleaningFrequency": "string (hourly/daily/weekly)",
  "cleaningCrew": "string",
  "cleaningMethod": "string (manual/mechanized)",
  "detergentsUsed": "array",
  "timeTaken": "float (minutes)",
  "qualityCheckPassed": "boolean"
},
"passengerFeedback": {
  "ratingAverage": "float (1-5)",
  "totalRatings": "int",
  "complaintCount": "int",
  "complaintTypes": "array",
}
```

```

    "appreciationCount": "int",
    "photoSubmissions": "array (URLs)"
},
"compliance": {
    "swachhBharatScore": "float (0-100)",
    "isoStandard": "string (ISO 9001/14001)",
    "complianceStatus": "string (compliant/non-compliant)",
    "penaltiesIssued": "int",
    "improvementActions": "array"
},
"predictions": {
    "nextCleaningRequired": "ISO8601",
    "crowdImpactOnCleanliness": "float (0-1)",
    "predictedCleanlinessDecay": "object (hourly forecast)",
    "resourceRequirement": "object (crew, materials)"
}
}
}

```

AI/ML Algorithms:

1. Cleanliness Assessment: Computer Vision CNN

- Architecture: EfficientNet-B7 fine-tuned on railway environments
- Input: Camera images from stations/trains
- Output: Cleanliness score (0-100), detected issues
- Classes: Clean, moderately dirty, dirty, very dirty
- Object detection: Litter, stains, graffiti

2. Litter Detection & Classification: YOLOv8

- Real-time object detection
- Detects: Plastic bottles, bags, paper, food waste
- Bounding box + classification
- Enables automated alerts to cleaning crew

3. Air Quality Prediction: LSTM Time Series

- Forecasts AQI based on:
 - Footfall
 - Time of day
 - Weather conditions
 - Train movements
- Predicts when ventilation needs adjustment

4. Optimal Cleaning Schedule: Reinforcement Learning

- Algorithm: Proximal Policy Optimization (PPO)
- State: Current cleanliness levels, footfall, crew availability
- Action: Deploy crew to specific location
- Reward: Maintain cleanliness above threshold, minimize cost

5. Passenger Sentiment Analysis: NLP (BERT)

- Analyzes passenger feedback text
- Sentiment classification: Positive, Neutral, Negative
- Topic extraction: Identifies specific issues
- Trend detection: Spots recurring problems

6. Wastage Prediction: Random Forest Regression

- Predicts waste generation rate
- Features: Footfall, train frequency, time of day, events
- Output: Expected waste volume, bin fill time

Visualizations:

- Station cleanliness heatmap (floor plan overlay)
 - Train coach-wise cleanliness scores
 - Air quality trend charts
 - Litter density map
 - Cleaning crew deployment map
 - Compliance dashboard (Swachh Bharat scores)
 - Passenger feedback sentiment analysis
 - Before/after cleaning comparison images
 - Waste bin fill level gauges
-

3.2 Track & Infrastructure Cleanliness

Data Structure:

```
{  
  "infrastructureCleanliness": {  
    "timestamp": "ISO8601",  
    "location": {  
      "sectionCode": "string",  
      "kilometerPost": "float"  
    },  
    "trackCleanliness": {  
      "ballastContamination": "float (% fouled)",  
      "vegetationEncroachment": "boolean",  
      "vegetationHeight": "float (cm)",  
      "drainageBlockage": "boolean",  
      "waterLogging": "boolean",  
      "waterDepth": "float (mm)",  
      "debrisPresent": "boolean",  
      "animalCarcassDetected": "boolean"  
    },  
    "drainageSystem": {  
      "drainCondition": "string (clear/partially_blocked/fully_blocked)",  
      "flowRate": "float (liters/minute)",  
      "sedimentLevel": "float (%)",  
      "cleaningRequired": "boolean"  
    },  
    "risks": {  
      "floodRisk": "string (low/moderate/high)",  
      "trackStabilityRisk": "string (low/moderate/high)",  
      "wildlifeHazard": "boolean"  
    }  
  }  
}
```

}

AI/ML Algorithms:

1. **Vegetation Detection: Semantic Segmentation (U-Net)**
 - o Satellite/drone imagery analysis
 - o Identifies encroaching vegetation
 - o Estimates growth rate
 - o Prioritizes cutting zones
 2. **Drainage Blockage Prediction: Time Series + Weather Integration**
 - o Algorithm: Prophet + Rainfall data
 - o Predicts blockage likelihood
 - o Suggests pre-monsoon cleaning
-

MODULE 4: SAFETY ANALYTICS & REPORTING

4.1 Incident Management System

Data Structure:

```
{  
  "safetyIncident": {  
    "incidentId": "string",  
    "timestamp": "ISO8601",  
    "type": "string (accident/near_miss/equipment_failure/SPAD/derailment)",  
    "severity": "string (minor/moderate/serious/critical/catastrophic)",  
    "location": {  
      "stationCode": "string",  
      "kilometerPost": "float",  
      "trackNumber": "int"  
    },  
    "involvedEntities": {  
      "trains": "array",  
      "passengers": "int",  
      "staff": "int",  
      "infrastructure": "array"  
    }  
  }  
}
```

```
        },
        "casualties": {
            "fatalities": "int",
            "seriousInjuries": "int",
            "minorInjuries": "int"
        },
        "rootCause": {
            "primaryCause": "string",
            "contributingFactors": "array",
            "humanError": "boolean",
            "equipmentFailure": "boolean",
            "environmentalFactor": "boolean",
            "systemicIssue": "boolean"
        },
        "response": {
            "responseTime": "float (minutes)",
            "emergencyServicesAlerted": "boolean",
            "evacuationRequired": "boolean",
            "trafficDisruption": "object",
            "investigationStatus": "string"
        },
        "preventiveMeasures": {
            "immediateActions": "array",
            "longTermActions": "array",
            "budgetRequired": "float",
            "implementationTimeline": "string"
        }
    }
}
```

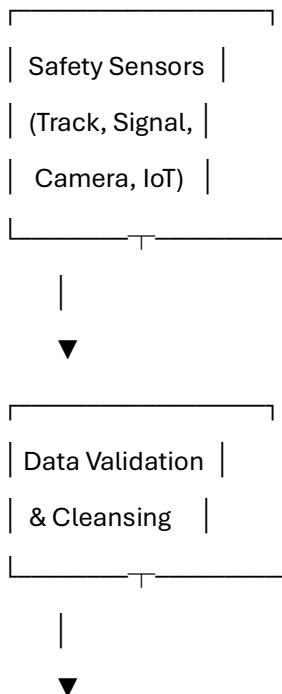
AI/ML Algorithms:

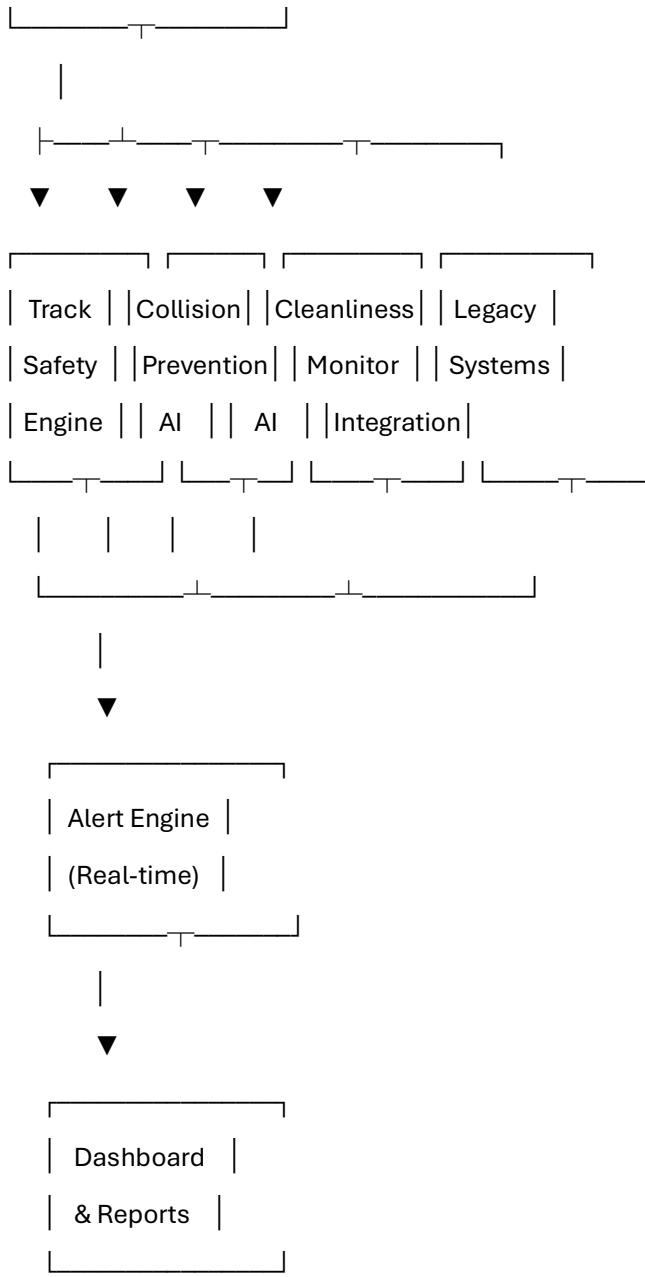
1. **Root Cause Analysis: Bayesian Network**

- Models causal relationships
 - Identifies primary and contributing factors
 - Suggests preventive measures
- 2. Incident Prediction: Classification (XGBoost)**
- Features: Track conditions, weather, train load, driver behavior
 - Output: Incident probability for each route section
- 3. Pattern Recognition in Incidents: Clustering (DBSCAN)**
- Groups similar incidents
 - Identifies systemic issues
 - Reveals hidden correlations
-

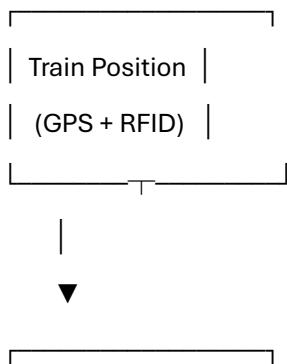
SYSTEM FLOWCHARTS

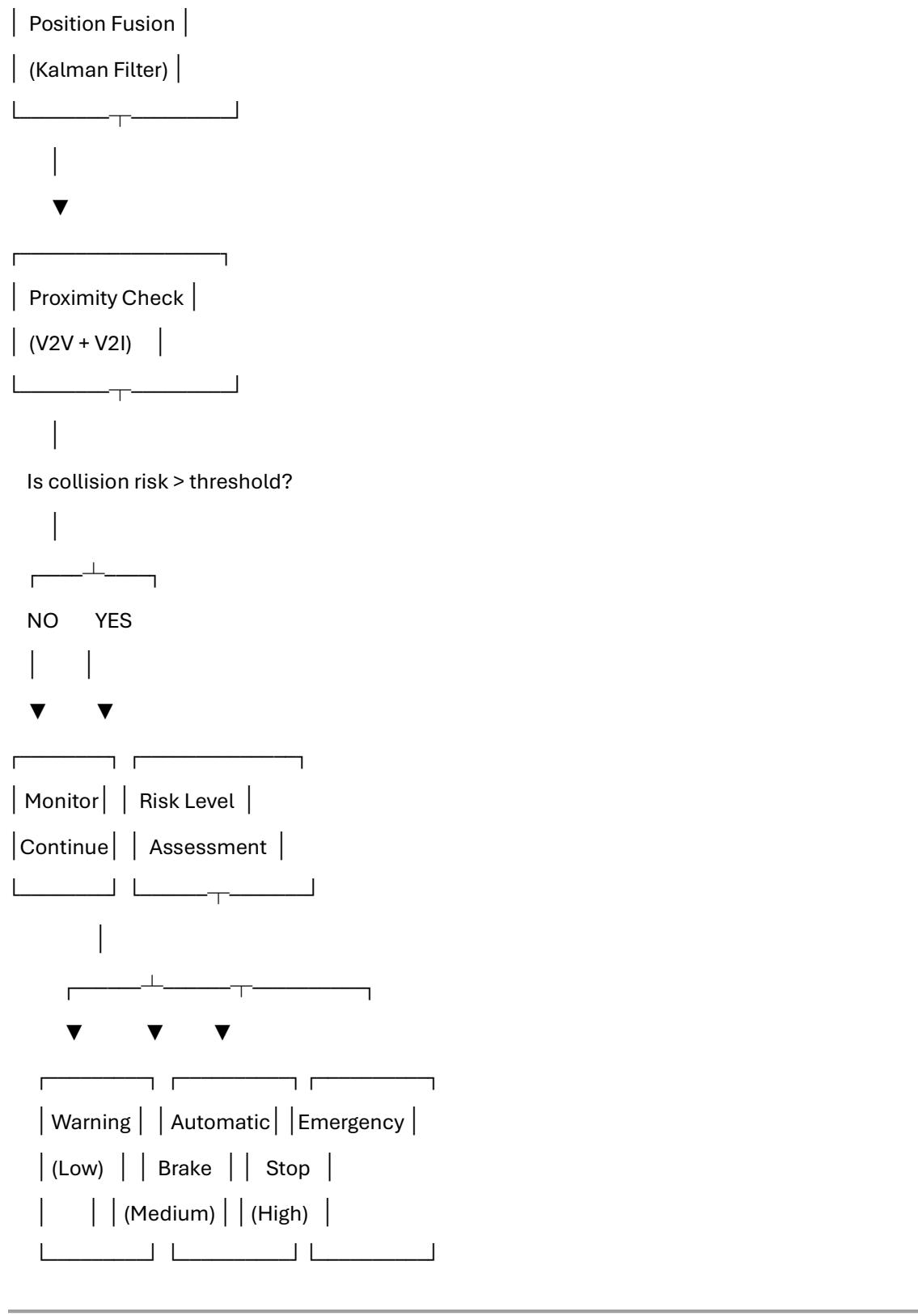
Overall Safety Data Flow





Collision Prevention Decision Flow





REVENUE STREAMS (SAFETY MODULE)

1. Safety Data Licensing

- Incident analytics: ₹5-20 Lakhs/year per organization
 - Predictive safety insights: ₹10-50 Lakhs/year
 - Benchmarking reports: ₹2-10 Lakhs per report
2. **Collision Prevention System Licensing**
- Per-train licensing: ₹50,000-2 Lakhs/year
 - Network-wide licensing: Custom pricing
3. **Cleanliness Monitoring SaaS**
- Per station: ₹25,000-1 Lakh/month
 - Enterprise (zone-wide): ₹10-50 Lakhs/month
4. **Compliance Reporting**
- Automated compliance reports: ₹1-5 Lakhs per report
 - Real-time compliance dashboard: ₹5-20 Lakhs/year
5. **Safety Consulting**
- Risk assessment services: Project-based
 - Safety audit automation: ₹10-50 Lakhs per audit

TECHNOLOGY STACK (SAFETY MODULE)

Frontend:

- React.js with TypeScript
- Leaflet.js for mapping
- Recharts for visualizations
- Tailwind CSS

Backend:

- Node.js with Express
- Python FastAPI for ML services
- GraphQL API

AI/ML:

- TensorFlow / PyTorch (Deep Learning)
- OpenCV (Computer Vision)
- Scikit-learn (Classical ML)
- ONNX Runtime (Model deployment)

Databases:

- PostgreSQL + PostGIS (Spatial data)
- MongoDB (Incident reports)
- InfluxDB (Time-series sensor data)
- Redis (Real-time cache)

Infrastructure:

- Docker / Kubernetes
- AWS / Azure
- Apache Kafka (Real-time streaming)
- Apache Airflow (Data pipelines)

Communication:

- MQTT (IoT devices)
 - 5G/LTE (Train-to-Infrastructure)
 - LoRaWAN (Track sensors in remote areas)
-

 **LOVABLE.DEV PROMPTS****PROMPT 1: Safety Metrics - Track Safety Dashboard**

Create a "Track Safety Monitoring" dashboard within the Safety Metrics module with the following features:

TECH STACK:

- React with TypeScript
- Tailwind CSS for styling
- Recharts for visualizations
- Leaflet.js for geographic mapping
- Shadcn/ui components
- Lucide React for icons

LAYOUT STRUCTURE:**1. Top Filter Bar:**

- Zone selector (dropdown: North/South/East/West/Central/All)
- Section search (autocomplete: DLI-NDLS-SEC-5)
- Date range picker

- Risk level filter (checkboxes: Low, Moderate, High, Critical)
 - "Apply Filters" button
- 2. Key Metrics (Top Row - 5 Cards):**
- Track Sections Monitored (count with icon)
 - Critical Risk Alerts (count with red badge)
 - Average Track Health Score (0-100 with gauge)
 - Maintenance Pending (count with warning icon)
 - Speed Restrictions Active (count)
- 3. Geographic Track Health Map:**
- Interactive map using Leaflet.js
 - Color-coded track sections:
 - Green: Healthy (score 80-100)
 - Yellow: Moderate (score 60-79)
 - Orange: Poor (score 40-59)
 - Red: Critical (score 0-39)
 - Click section to see detailed metrics
 - Zoom controls
 - Layer toggles: Track condition, Signal systems, Speed restrictions
 - Popup showing: Section ID, Health score, Last inspection, Alerts
- 4. Track Geometry Trends Chart:**
- Multi-line chart with switchable metrics:
 - Gauge deviation
 - Cross level
 - Alignment
 - Surface irregularity
 - Twist
 - X-axis: Time (Last 7 days / Last 30 days / Last 6 months)
 - Y-axis: Deviation in mm
 - Threshold lines (acceptable limits)
 - Anomaly markers (red dots)
 - Export chart button

5. Risk Assessment Matrix:

- 2x2 matrix scatter plot:
 - X-axis: Failure Probability (0-1)
 - Y-axis: Impact Severity (0-100)
 - Quadrants: Monitor, Plan, Urgent, Emergency
- Each point represents a track section
- Size: Represents length of section
- Color: Represents risk category
- Click to see section details

6. Track Defects Table:

- Columns:
 - Section ID (clickable)
 - Kilometer Post
 - Defect Type (Crack/Corrosion/Geometry/Sleeper/Ballast)
 - Severity (badge with color)
 - Detected Date
 - Predicted Failure Date
 - Maintenance Priority (Low/Medium/High/Emergency)
 - Status (Open/In Progress/Resolved)
 - Actions (View, Schedule Maintenance)
- Sortable columns
- Row color coding by severity
- Pagination (50 items per page)
- Export to CSV

7. Predictive Maintenance Timeline:

- Gantt chart showing:
 - Scheduled maintenance (blue bars)
 - Predicted failures (red markers)
 - Optimal maintenance windows (green highlights)
- X-axis: Next 90 days
- Y-axis: Track sections

- Hover to see details
- Drag to reschedule (if authorized)

8. AI Insights Panel (Sidebar):

- "Top Recommendations" list:
 - Each recommendation shows:
 - Description
 - Expected impact
 - Urgency level
 - Cost estimate
 - "Accept" or "Defer" buttons
- "Detected Patterns" section:
 - Recurring issues
 - Correlation insights
- "Resource Optimization" suggestions

TRACK DETAIL MODAL: When clicking a track section, show modal with tabs:

a) Overview Tab:

- Section information
- Current health score (large gauge)
- Last inspection details
- Inspector name and notes
- Photo gallery

b) Geometry Metrics Tab:

- All geometry parameters with values
- Comparison to standards
- Historical trend sparklines
- Download data button

c) Defects & Alerts Tab:

- List of detected defects
- Alert history
- Photos of defects
- Maintenance actions taken

d) Predictive Analysis Tab:

- AI-generated insights
- Failure probability curve
- Recommended actions
- Cost-benefit analysis

e) Maintenance History Tab:

- Timeline of all maintenance
- Before/after metrics
- Cost tracking
- Effectiveness analysis

MOCK DATA:

```
{  
  "sectionId": "DLI-NDLS-SEC-5",  
  "kilometerPost": 12.5,  
  "healthScore": 68,  
  "riskCategory": "moderate",  
  "gaugeDeviation": 3.2,  
  "crossLevel": 1.8,  
  "alignment": 2.5,  
  "crackDetected": true,  
  "crackLength": 45,  
  "failureProbability": 0.35,  
  "timeToFailure": 45,  
  "lastInspection": "2026-01-20T08:30:00Z",  
  "maintenancePriority": "high"  
}
```

INTERACTIVE FEATURES:

- Real-time updates (every 30 seconds)
- Click any chart element to drill down
- Export all data as PDF report
- Schedule maintenance directly from dashboard

- Send alerts to maintenance team
- Mobile-responsive for field inspections

DESIGN REQUIREMENTS:

- Color scheme: Green (safe), Yellow (caution), Orange (warning), Red (critical)
- Large, readable fonts for control room display
- Dark mode option for 24/7 operations
- Loading skeletons while data loads
- Error states with retry options
- Success confirmations for actions

PROMPT 2: Safety Metrics - Collision Prevention Dashboard

Create a "Collision Prevention System" dashboard with real-time train tracking and collision risk monitoring:

LAYOUT STRUCTURE:

1. Real-time Train Position Map (Central Feature):

- Full-width interactive map
- Train icons (color-coded by type: Express=blue, Freight=orange, Local=green)
- Train direction arrows
- Speed labels on each train
- Collision risk proximity circles:
 - Green circle (safe distance)
 - Yellow circle (monitor)
 - Red circle (warning)
- Signal positions with current aspect (colored dots)
- Track layout with section boundaries
- Live update every 2 seconds
- Click train to see details

2. System Status Panel (Top Right):

- 6 status cards:
 - Kavach System (Active/Inactive with green/red indicator)
 - AWS Status (count active/total)

- TPWS Status (count active/total)
- ACD Status (count active/total)
- GPS Quality (average % across all trains)
- Communication Quality (average % across network)
- Overall system health score (0-100 gauge)

3. Active Risk Alerts (Left Sidebar):

- Real-time scrolling list of alerts
- Each alert shows:
 - Timestamp
 - Alert type (icon: collision risk/SPAD/system failure)
 - Train IDs involved
 - Risk level (color badge)
 - Distance/Time to incident
 - Auto-actions taken (if any)
 - "View Details" button
- Sort by severity
- Filter by alert type
- Acknowledge button

4. Train-to-Train Proximity Table:

- Shows all train pairs within critical distance
- Columns:
 - Train A ID
 - Train B ID
 - Relative Distance (meters)
 - Closing Rate (m/s)
 - Time to Collision (seconds) - red if <60s
 - Risk Score (0-100)
 - Auto-Brake Status
 - Manual Override Available
- Auto-refresh every 5 seconds
- Sound alarm if risk >80

5. Legacy Systems Integration Dashboard:

- Three sections side-by-side:

a) AWS (Auxiliary Warning System):

- Map showing AWS-equipped sections (Mumbai suburban)
- Magnet status (working/stolen/faulty)
- Last maintenance dates
- Replacement schedule

b) TPWS (Train Protection Warning System):

- Coverage map
- Transponder status grid
- System availability %
- Cost per km (₹15-20 lakhs display)
- Scalability issues noted

c) ACD (Anti-Collision Device):

- GPS quality heatmap
- Radio interference zones
- SIL-4 compliance status (Non-compliant warning)
- Historical performance data
- Comparison table: AWS vs TPWS vs ACD vs Kavach
- Migration timeline (from legacy to modern)

6. Signal Passed At Danger (SPAD) Monitor:

- SPAD event counter (last 24 hours / 7 days / 30 days)
- List of SPAD events:
 - Train ID
 - Signal ID
 - Timestamp
 - Driver name
 - Speed at pass
 - Distance passed
 - Reason (if known)
 - Action taken

- SPAD risk heatmap (geographic)
- Preventive measures tracking

7. Collision Prevention Analytics:

- Time series chart: Collision risks detected over time
- Bar chart: Auto-brake activations per day
- Pie chart: Alert distribution by type
- Success rate: % of collisions prevented
- Near-miss statistics
- System uptime percentage

8. Train Detail Panel (Click any train):

- Train ID and type
- Current location (map + coordinates)
- Speed gauge (current vs max allowed)
- Acceleration indicator
- Signal ahead (distance + aspect)
- System status:
 - Kavach: Active/Inactive
 - GPS Accuracy: $\pm 0.5\text{m}$ indicator
 - Communication: Strong/Weak
- Nearby trains list (within 5 km)
- Driver information
- Last auto-brake event
- Override history (if any)

MOCK DATA:

```
{
```

```
  "trainId": "12345-EXP",
```

```
  "latitude": 28.6139,
```

```
  "longitude": 77.2090,
```

```
  "currentSpeed": 95,
```

```
  "heading": 145,
```

```
  "nearbyTrains": [
```

```
{  
    "trainId": "67890-FRT",  
    "relativeDistance": 1200,  
    "relativeSpeed": -15,  
    "collisionRisk": 0.65,  
    "timeToCollision": 45  
}  
,  
    "kavachStatus": "active",  
    "awsStatus": "inactive",  
    "tpwsStatus": "active",  
    "gpsQuality": 98,  
    "automaticBrakeApplied": false,  
    "collisionProbability": 0.12  
}
```

ALERT LOGIC:

- Green zone: Distance >2000m, Risk <30
- Yellow zone: Distance 1000-2000m, Risk 30-60
- Orange zone: Distance 500-1000m, Risk 60-80
- Red zone: Distance <500m, Risk >80
- Emergency brake: Risk >90 or Time to Collision <30s

INTERACTIVE FEATURES:

- Play/pause live updates
- Rewind to review past 30 minutes
- Simulate collision scenarios (testing mode)
- Manual override request (authorized users only)
- Export incident reports
- Send alerts to train drivers and control room
- Voice announcements for critical alerts

DESIGN:

- High-contrast colors for visibility

- Large fonts for control room screens
 - Sound alerts (configurable)
 - Flashing indicators for critical risks
 - Dark mode for night operations
 - Mobile app companion for field officers
-

PROMPT 3: Safety Metrics - Cleanliness Monitoring Dashboard

Create a "Cleanliness Monitoring" dashboard with AI-powered visual inspection and IoT sensors:

LAYOUT STRUCTURE:

1. Station/Train Selector (Top):

- Dropdown: Select Station (autocomplete search)
- Dropdown: Select Train (if applicable)
- Tabs: Station View / Train View / Track View
- Date picker for historical analysis

2. Overall Cleanliness Score (Top Row - 4 Cards):

- Station Cleanliness Score (0-100 with gauge, color-coded)
- Train Cleanliness Score (0-100 with gauge)
- Swachh Bharat Compliance (% with green checkmark if >80%)
- Passenger Satisfaction (average rating 1-5 stars)

3. Station Floor Plan with Cleanliness Heatmap:

- Interactive floor plan (SVG or image overlay)
- Color overlay showing cleanliness levels:
 - Dark green: Excellent (90-100)
 - Light green: Good (70-89)
 - Yellow: Fair (50-69)
 - Orange: Poor (30-49)
 - Red: Very Poor (0-29)
- Areas: Platforms, Waiting halls, Toilets, Food courts, Ticket counters, Entry/Exit
- Click area to see detailed metrics
- Show cleaning crew current positions (live dots)

4. AI Visual Inspection (Computer Vision Results):

- Grid of camera feeds (4x2 layout)
- Each feed shows:
 - Location label
 - Live/Snapshot toggle
 - Detected issues overlay (bounding boxes):
 - Litter (yellow box)
 - Stains (orange box)
 - Graffiti (red box)
 - Cleanliness score for that area
 - "View Full Analysis" button
- Auto-refresh every 10 seconds

5. Litter Detection & Classification:

- Real-time litter count (number with trash icon)
- Litter breakdown pie chart:
 - Plastic bottles
 - Plastic bags
 - Paper
 - Food waste
 - Other
- Litter heatmap (geographic on floor plan)
- "Deploy Cleaning Crew" button for each hotspot

6. Air Quality Monitoring:

- Multi-line chart (last 24 hours):
 - AQI (primary Y-axis)
 - CO2 levels (secondary Y-axis)
 - PM2.5 (secondary Y-axis)
 - PM10 (secondary Y-axis)
- Current values in large text with color coding:
 - Green: Good (AQI 0-50)
 - Yellow: Moderate (51-100)

- Orange: Unhealthy for Sensitive Groups (101-150)
- Red: Unhealthy (151-200)
- Purple: Very Unhealthy (201-300)
- Ventilation status: Active/Inactive
- "Adjust Ventilation" button

7. Toilet Hygiene Monitor:

- List of toilets with status:
 - Toilet ID
 - Cleanliness score (0-100)
 - Water availability (icon)
 - Soap dispenser level (% gauge)
 - Odor level (0-100 with nose icon)
 - Last cleaned (timestamp)
 - Footfall since last cleaning
 - "Needs Cleaning" alert (red badge)
- Click toilet to see detailed sensor data
- "Dispatch Cleaner" button

8. Waste Bin Monitoring:

- Grid of waste bin cards:
 - Bin ID and location
 - Fill level gauge (0-100%)
 - Green: 0-60%
 - Yellow: 60-80%
 - Orange: 80-95%
 - Red: >95%
 - Last emptied timestamp
 - Predicted time to full (AI forecast)
 - Type: General/Recyclable/Hazardous
- "Empty Now" button for >90% full bins
- Optimal collection route suggestion

9. Cleaning Crew Management:

- Table of active crews:
 - Crew ID and name
 - Current location (map marker)
 - Assigned area
 - Task status (In Progress/Completed)
 - Time since task started
 - Quality check pending
- "Assign New Task" button
- Crew performance metrics (tasks completed today, average quality score)

10. Passenger Feedback Dashboard:

- Average rating gauge (1-5 stars)
- Sentiment breakdown pie chart (Positive/Neutral/Negative)
- Recent feedback scrolling list:
 - Rating (stars)
 - Comment text
 - Photo (if submitted)
 - Timestamp
 - Area/Train coach
 - "Respond" button
- Word cloud of frequent topics
- Trend chart: Rating over time

11. Cleanliness Trends & Analytics:

- Line chart: Daily cleanliness scores (last 30 days)
- Bar chart: Cleanliness by area comparison
- Correlation chart: Footfall vs Cleanliness decay
- Heatmap: Hour of day vs Area cleanliness (identify peak dirty times)

12. Compliance & Reporting:

- Swachh Bharat audit checklist (% complete)
- ISO certification status
- Penalties issued (count and amount)
- Improvement actions tracker

- "Generate Compliance Report" button (PDF export)

CLEANLINESS DETAIL MODAL: When clicking an area on floor plan:

a) **Visual Inspection Tab:**

- Camera images (before/after cleaning)
- AI-detected issues list with photos
- Cleanliness score breakdown (floor/walls/ceiling)

b) **Sensor Data Tab:**

- All sensor readings with gauges
- Historical trends
- Threshold violations

c) **Maintenance Log Tab:**

- Cleaning history timeline
- Crew names and methods used
- Time taken per cleaning
- Quality check results

d) **Predictions Tab:**

- Next cleaning required time
- Resource requirements (crew, materials)
- Cost estimate

MOCK DATA:

```
{  
  "stationCode": "NDLS",  
  "area": "Platform 3",  
  "cleanlinessScore": 72,  
  "floorCleanliness": 68,  
  "toiletHygiene": 81,  
  "litterDetected": true,  
  "litterCount": 12,  
  "airQualityIndex": 95,  
  "co2Level": 850,  
  "pm2_5": 42,
```

```
"wasteBinFillLevel": 78,  
"lastCleaned": "2026-01-29T06:30:00Z",  
"passengerRating": 3.8,  
"nextCleaningRequired": "2026-01-29T14:00:00Z"  
}
```

INTERACTIVE FEATURES:

- Real-time camera feed toggle
- Time-lapse view (show cleanliness decay over day)
- Compare multiple areas side-by-side
- Schedule automated cleaning
- Send instant alerts to cleaning supervisor
- Mobile app for cleaning crew
- QR code generation for spot checks
- Gamification: Crew leaderboard

DESIGN:

- Clean, hygienic aesthetic (white/blue theme)
- Clear iconography (trash, soap, water)
- Progress bars and gauges for fill levels
- Before/after image comparisons
- Smooth animations
- Accessible for cleaning staff with varying tech skills

PROMPT 4: Safety Metrics - Legacy Systems Integration Page

Create a dedicated "Legacy Safety Systems" integration and comparison page:

LAYOUT STRUCTURE:

1. Historical Timeline (Top Section):

- Horizontal timeline showing:
 - 1980s: Manual operations
 - 1990s: AWS introduction (Mumbai)
 - 2000s: ACD development (Konkan Railway + Kernex)
 - 2010s: TPWS trials

- 2020s: Kavach rollout
 - Click each era to see details
 - Photos/diagrams of each system
- 2. System Comparison Matrix (Main Section):**
- Large comparison table with columns:
 - Feature / AWS / TPWS / ACD / Kavach (Modern)
 - Rows:
 - Technology Type
 - Coverage (route km)
 - Cost per km
 - Data Capacity
 - Safety Integrity Level (SIL)
 - Theft Vulnerability
 - Weather Dependency
 - Scalability
 - Train-to-Train Communication
 - Continuous Speed Monitoring
 - Real-time GPS
 - Fail-Safe Compliance
 - Deployment Complexity
 - Maintenance Cost
 - Color coding: Green (good), Yellow (moderate), Red (poor)
 - Icons for quick visual comparison

3. AWS (Auxiliary Warning System) Deep Dive:

- Description card:
 - Technology: Track magnets + onboard receivers
 - Primary use: Mumbai suburban network
 - Limitations in bullet points
 - Coverage map (geographic - Mumbai highlighted)
 - Performance statistics:
 - Total magnets installed

- Theft incidents (count and trend chart)
- Effectiveness rate
- Operational cost
- Photos: Track magnet, onboard equipment
- Migration plan to Kavach timeline

4. TPWS (Train Protection Warning System) Deep Dive:

- Description card:
 - Technology: ETCS Level 1 based
 - European standard adaptation
 - Infrastructure: Transponders + cables
- Cost analysis:
 - Cost per km: ₹15-20 lakhs (highlighted in large text)
 - Total cost for 68,000 km network: ₹1,02,000 - ₹1,36,000 Crores
 - Comparison bar chart vs other systems
- Deployment challenges:
 - Extensive cabling requirements (diagram)
 - Weather sensitivity issues
 - Maintenance complexity
- Trial sections map (where implemented)
- Performance metrics from trial sections

5. ACD (Anti-Collision Device) Deep Dive:

- History card:
 - Developer: Konkan Railway + Kernex partnership
 - Era: Early 2000s
 - Status: Precursor, not complete solution
- Technology breakdown:
 - GPS-based positioning (accuracy issues noted)
 - Radio communication (interference problems)
 - Architecture diagram
- Limitations detailed:
 - SIL-4 certification: FAILED (red badge)

- GPS accuracy in tunnels/dense areas: POOR
- Radio interference: HIGH
- Fail-safe compliance: NO
- Lessons learned list
- Evolution to modern systems flow diagram

6. Kavach (Modern System) Showcase:

- Description: Indigenous TCAS (Train Collision Avoidance System)
- Technology advantages:
 - Multi-sensor fusion (GPS + RFID + 5G)
 - SIL-4 certified (green checkmark)
 - Affordable: ₹30-50 lakhs per km
 - Scalable for entire network
- Deployment map (current coverage + planned)
- Performance dashboard (live data)
- Comparison to international systems (ATP, ETCS, PTC)

7. Migration Roadmap:

- Gantt chart showing phased migration:
 - Phase 1: Critical corridors (Delhi-Mumbai, Delhi-Howrah)
 - Phase 2: High-density routes
 - Phase 3: Suburban networks (replace AWS)
 - Phase 4: Complete national coverage
- Timeline: 2024-2030
- Budget allocation bar chart
- Milestones with checkpoints

8. Cost-Benefit Analysis:

- Interactive calculator:
 - Input: Route length (km)
 - Select system: AWS/TPWS/ACD/Kavach
 - Output:
 - Installation cost
 - Annual maintenance

- 10-year total cost
- Safety incidents prevented (estimated)
- ROI calculation
- Comparison chart for all systems
- Break-even analysis

9. Technical Documentation Library:

- Downloadable documents:
 - AWS Technical Specifications (PDF)
 - TPWS Implementation Guide (PDF)
 - ACD Research Papers (PDF)
 - Kavach System Manual (PDF)
 - Safety Standards (SIL-4 explained)
- Video tutorials
- Training modules

INTERACTIVE FEATURES:

- Side-by-side system comparison toggle
- Cost calculator with real-time updates
- Migration simulator (what-if scenarios)
- Export comparison report (PDF)
- Comment section for railway engineers
- Case study viewer (successful implementations)

DESIGN:

- Professional, technical aesthetic
- Blueprint-style backgrounds
- Color coding: Legacy systems (sepia tone), Modern (vibrant)
- Icons representing each technology
- Infographics for complex concepts
- Accessible for policy makers and engineers

PROMPT 5: Safety Analytics - Incident Management System

Create an "Incident Management & Reporting" system:

LAYOUT STRUCTURE:

1. Incident Dashboard Overview:

- 6 KPI cards:
 - Total Incidents (count with trend)
 - Fatalities (count - red if >0)
 - Serious Injuries (count)
 - Minor Incidents (count)
 - Average Response Time (minutes)
 - Open Investigations (count)

2. Incident Map:

- Geographic map showing all incidents
- Markers color-coded by severity:
 - Minor: Yellow
 - Moderate: Orange
 - Serious: Red
 - Critical: Dark Red
 - Catastrophic: Black
- Click marker to see incident summary
- Heat map layer (incident density)
- Filter by date range, type, severity

3. Incident Log Table:

- Columns:
 - Incident ID
 - Date & Time
 - Type (Accident/Near-Miss/SPAD/Derailment/Equipment Failure)
 - Severity
 - Location (Station + KM post)
 - Trains Involved
 - Casualties (Fatalities/Injuries)
 - Status (Reported/Investigating/Resolved/Closed)
 - Actions

- Advanced filters
- Export to Excel/PDF
- Click row to open detailed view

4. Incident Detail Modal:

- Tabs:

a) Overview:

- Incident summary
- Timeline of events
- Location map
- Photos/videos

b) Involved Entities:

- Trains (IDs, types)
- Passengers (count)
- Staff (names, roles)
- Infrastructure (damaged assets)

c) Casualties:

- List of affected persons (anonymized)
- Medical reports
- Compensation tracking

d) Root Cause Analysis:

- AI-generated causal diagram (Bayesian network visualization)
- Primary cause
- Contributing factors (checkboxes):
 - Human error
 - Equipment failure
 - Environmental factor
 - Systemic issue
- Investigation notes

e) Response:

- Response timeline
- Emergency services alerted (timestamp)

- Evacuation details
- Traffic disruption (trains affected)
- Media coverage

f) Preventive Measures:

- Immediate actions taken (list)
- Long-term actions recommended
- Budget required
- Implementation timeline
- Responsible department
- Status tracker

5. Root Cause Analysis Tool:

- Interactive Fishbone (Ishikawa) diagram builder
- Categories: People, Process, Equipment, Environment, Management
- Drag-and-drop causes
- AI suggestions based on similar incidents
- Export diagram as image

6. Incident Prediction Dashboard:

- Risk heatmap: Route sections with high incident probability
- Predictive alerts:
 - Location
 - Predicted incident type
 - Probability (%)
 - Recommended preventive actions
- Time series: Incident prediction trends
- Feature importance chart (what factors contribute most)

7. Pattern Recognition:

- Cluster visualization (DBSCAN results)
- Groups of similar incidents highlighted
- Common patterns identified:
 - "Track geometry issues on monsoon routes"
 - "Signal failures during extreme heat"

- "Human error in night shifts"
- Drill down to see incidents in each cluster

8. Safety Metrics Over Time:

- Line charts:
 - Incidents per month (last 12 months)
 - Severity trend
 - Response time trend
 - Fatality rate
- Year-over-year comparison
- Benchmark against international standards

9. Investigation Workflow:

- Kanban board:
 - Reported
 - Preliminary Investigation
 - Detailed Investigation
 - Root Cause Identified
 - Preventive Actions
 - Closed
- Drag incidents between stages
- Assignment to investigators
- Deadline tracking
- Status notifications

10. Compliance & Reporting:

- Generate official reports (templates):
 - Accident Inquiry Report
 - Commissioner of Railway Safety (CRS) Report
 - Parliamentary Report
 - Media Brief
- Auto-populate from incident data
- Export as PDF
- Digital signatures

- Email to stakeholders

MOCK DATA:

```
{  
  "incidentId": "INC-2026-001",  
  "timestamp": "2026-01-28T14:30:00Z",  
  "type": "derailment",  
  "severity": "serious",  
  "location": {  
    "stationCode": "NDLS",  
    "kilometerPost": 25.3  
  },  
  "trainsInvolved": ["12345"],  
  "casualties": {  
    "fatalities": 0,  
    "seriousInjuries": 3,  
    "minorInjuries": 12  
  },  
  "rootCause": {  
    "primaryCause": "track_geometry_deviation",  
    "humanError": false,  
    "equipmentFailure": true  
  },  
  "responseTime": 8.5,  
  "investigationStatus": "ongoing"  
}
```

INTERACTIVE FEATURES:

- Real-time incident reporting (mobile app integration)
- Photo/video upload
- Voice notes from field officers
- Live chat with investigation team
- Automated stakeholder notifications

- Timeline playback (reconstruct incident)

DESIGN:

- Serious, professional tone
 - Red color sparingly (for critical severity)
 - Clear status indicators
 - Accessible for investigators and management
 - Print-friendly report layouts
 - Secure (role-based access)
-

INTEGRATION & FINAL POLISH

Global Safety Dashboard Integration:

1. Unified Safety Score:

- Combines: Track Safety + Collision Prevention + Cleanliness
- Weighted average: Track (40%), Collision (40%), Cleanliness (20%)
- Display: Large gauge on main dashboard (0-100)
- Color: Green >80, Yellow 60-80, Orange 40-60, Red <40

2. Real-time Alert Aggregation:

- All alerts from all modules in one feed
- Priority sorting
- Smart grouping (related alerts bundled)
- Escalation rules
- Mobile push notifications

3. Cross-module Insights:

- Correlation analysis:
 - Poor track maintenance → Higher collision risk
 - Low cleanliness → Lower passenger satisfaction → Safety complaints
- Unified reporting
- Executive summary dashboard

4. API Integration:

- RESTful API for external systems
- Webhook support for real-time events

- Data export (JSON, CSV, XML)
 - Third-party tool integration (GIS, ERP)
-

TRAINING & ADOPTION

Training Modules:

1. Safety Officer Training (Dashboard usage)
2. Cleaning Staff Mobile App Training
3. Maintenance Crew Prediction Tool Training
4. Control Room Operator Training (Collision prevention)
5. Investigation Team Root Cause Analysis Tool

Change Management:

- Phased rollout plan
 - User feedback loops
 - Continuous improvement
 - Performance incentives
-

SECURITY & COMPLIANCE

Security Measures:

- Role-based access control (RBAC)
- Data encryption (at rest and in transit)
- Audit logs for all actions
- Secure API authentication (OAuth 2.0)
- Regular security audits
- Incident response plan

Compliance:

- Indian Railways safety standards
- ISO 9001 (Quality Management)
- ISO 14001 (Environmental Management)
- SIL-4 certification for collision prevention
- Swachh Bharat Mission guidelines
- Data privacy (Personal Data Protection Act)

This comprehensive documentation provides everything needed to build the **Safety Metrics Module** for RailSync Pro using Lovable.dev, complete with AI algorithms, data structures, visualizations, and integration with legacy systems.