

Predictive Maintenance & Failure Classification for Mining Vehicles

Objective

Implement an AI-driven predictive maintenance system for mining vehicles (e.g. excavator, tippers, loaders) that classifies component-level conditions such as oil filter health, brake wear, and engine anomalies to reduce downtime, increase safety, and optimize maintenance schedules.

Target Vehicles

Excavator
Tippers
Loaders

Key Predictive Maintenance Goals

- Reduce unplanned breakdowns
- Predict component failure before it occurs
- Optimize maintenance intervals
- Automate inspection alerts

Sensors Used (On-Vehicle)

Sensor Type	Parameters Measured	Component Monitored
Vibration Sensor	Shaft imbalance, bearing faults	Engine, transmission, wheels
Oil Quality Sensor	Viscosity, particles, water	Engine oil, hydraulic fluid
Pressure Sensor	System pressure, leaks	Brake lines, hydraulics
Temperature Sensor	Overheating, cooling failure	Engine, coolant system
Current Sensor	Electrical load	Motors, starters, alternators
RPM Sensor	Speed fluctuation	Engine crank, driveshaft
Acoustic Sensor	Ultrasonic noise, leaks	Air lines, valves
Brake Pad Sensor	Pad thickness	Brake system

Failure Classification Categories (Labeling for ML)

1. Engine System

Class Label	Description
Normal	All readings within expected range
Minor overheating	Mild temperature rise, early-stage issue
Oil contamination	Viscosity drop or particle increase
Imminent failure	Combined high heat, pressure drop

2. Oil Filter System

Class Label	Description
Clean	Normal flow, low particle load
Slightly clogged	Slight pressure drop or dirt rise
Heavily clogged	Severe flow reduction, bypass risk
Filter failure	No filtration, metal shavings

3. Brake System

Class Label	Description
Normal	Pad > 75%, no leaks
Worn pads	Pad < 50%, acceptable braking
Hydraulic leak	Pressure drop in lines
Brake failure risk	Critical wear or fluid loss

4. Hydraulic System

Class Label	Description
Normal	Stable pressure and temperature
Fluid degradation	Change in oil color, viscosity
Seal leakage	Drop in pressure or level
Cavitation/noise issue	Detected via acoustic sensors

5. Electrical System

Class Label	Description
Normal	Voltage/current within range
Alternator issue	Voltage drop during load
Battery nearing	Recharging inefficiency
Electrical short/fault	Sudden voltage spikes or drops

Maintenance Lifecycle Integration

1. Sensor Data Ingestion (Edge → Cloud)
2. Anomaly Detection (Real-time signal filtering)
3. Classification Model Inference
4. Component Condition Label Output
5. Computerized Maintenance Management System (CMMS) Trigger (Work order creation)
6. Technician Notification (Mobile app, dashboard)

Machine Learning Techniques

1. **Multi-class classification** (e.g., clean vs. clogged filter)
2. **Binary classifiers** (failure/no failure)
3. **Time-series forecasting** (remaining useful life)
4. **Sensor fusion** models (combine vibration + temp + oil)