SAFTEY ARTICLE
Operator Ranking & Analytics Model (ORAM)
A Data Driven Framework for Enhanced Mining Safety and Operational Excellence
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ABSTRACT

This paper presents the Operator Ranking & Analytics Model (ORAM), a comprehensive data driven framework designed to transform mining operations through intelligent operator assessment, predictive analytics, and enhanced safety protocols. ORAM addresses critical gaps in conventional operator evaluation systems by leveraging Vehicle Health Monitoring System (VHMS) and Fleet Management System (FMS) data to create transparent, unbiased performance metrics. The dual engine architecture comprising Behavioural (ORAM-B) and Mechanical (ORAM-M) modules enables proactive equipment monitoring, intelligent resource allocation, and continuous skill development. Implementation at Tata Steel's iron ore operations demonstrates 10-15% improvement in operator efficiency, 3-5% fuel savings, and significant reduction in safety incidents through predictive maintenance and behavioural optimization.

Keywords: Mining Safety, Operator Analytics, Predictive Maintenance, Fleet Management, Machine Learning, Behavioural Analytics

1. INTRODUCTION

Mining operations worldwide face persistent challenges in operator performance evaluation and equipment health management. Traditional assessment methodologies rely predominantly on attendance records and subjective experience-based judgment, creating significant gaps in operational safety and efficiency optimization. At Tata Steel's Katamati and Noamundi iron ore mines, the Vehicle Health Monitoring System (VHMS) and Fleet Management System (FMS) generate millions of data points daily, yet this wealth of information remains largely underutilized for proactive decision making.

The absence of standardized evaluation frameworks creates operational inefficiencies where identical equipment operated on the same routes exhibits 30-40% productivity variance. Fuel consumption patterns and breakdown occurrences remain untracked at the operator level, preventing targeted intervention and skill development. ORAM addresses these systemic challenges through a unified analytical framework that transforms raw operational data into actionable safety and performance insights.

2. PROBLEM ANALYSIS AND SAFETY IMPLICATIONS

Current state analysis reveals three critical safety and operational concerns requiring systematic intervention:

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2.1 Unstructured Evaluation Systems

Manual, attendance-based operator assessment provides no mechanism for identifying unsafe driving behaviors, excessive equipment stress, or inefficient operational patterns. Without objective metrics, operators exhibiting potentially hazardous practices such as aggressive acceleration, improper braking, or excessive idle times remain undetected until equipment failure or safety incidents occur.

2.2 Underutilized Monitoring Systems

VHMS and FMS technologies capture comprehensive vehicle telemetry including engine parameters, fuel consumption, geo location, and operational timestamps. However, siloed data management and reactive maintenance protocols prevent proactive identification of emerging equipment issues. Critical insights on fuel consumption patterns, cycle time anomalies, and component stress remain hidden within unused datasets.

2.3 Operational Impact on Safety

Inconsistent operator performance directly correlates with increased safety risks. Route specific challenges, equipment limitations, and environmental factors are not systematically factored into deployment decisions, leading to suboptimal operator equipment route combinations that elevate accident probability and equipment wear.

3. ORAM SOLUTION ARCHITECTURE

ORAM employs a dual engine architecture integrating behavioral and mechanical analytics to deliver comprehensive operational intelligence:

ORAM B (Behavioral System)	ORAM M (Mechanical System)
• Operator Skill Profiling & Benchmarking • Data Driven Allocation Decision Support • Operational Efficiency & Productivity Metrics • Route Normalized Performance Scoring	• Proactive Equipment Health Monitoring • Granular Trip Level Visual Analytics • Predictive Maintenance Diagnostics • Geospatial Detailed Haul road Mapping

Table 1: ORAM Dual Engine Module Components

4. MACHINE LEARNING DERIVED SAFETY METRICS

ORAM employs advanced machine learning algorithms to derive weighted performance metrics that directly correlate with safety outcomes. The model analyses operator controllable factors while normalizing for external variables such as route difficulty, equipment type, and material characteristics.

Performance Parameter	Weight	Safety Correlation
Productive Time Ratio (PTR)	31.83%	Minimizes fatigue related incidents
Hauling Speed Optimization	13.45%	Reduces collision risk
Route Normalized Performance	13.00%	Accounts for terrain hazards
TKPH Compliance	11.82%	Prevents tire related failures
Stop Time Management	11.52%	Reduces congestion hazards

Table 2: ML Derived Performance Weights and Safety Correlations

5. SAFETY OUTCOMES AND OPERATIONAL IMPACT

Implementation of ORAM at Tata Steel's iron ore operations has yielded measurable improvements across multiple safety and efficiency dimensions:

KEY PERFORMANCE IMPROVEMENTS

- 10-15% improvement in operator efficiency through data driven skill development.
- 3-5% reduction in fuel consumption via behavioural optimization and route intelligence
- 5-10% increase in material movement through predictive allocation
- Significant reduction in unplanned equipment downtime through VHMS analytics
- Enhanced safety compliance through transparent accountability mechanisms

6. CONCLUSION

ORAM represents a paradigm shift in mining operator management, transitioning from reactive, subjective assessment to proactive, data driven intelligence. By integrating behavioural analytics with mechanical diagnostics, the framework creates a comprehensive safety ecosystem that benefits operators, equipment, and organizational objectives. The transparent leaderboard system promotes positive behavioural change while the predictive maintenance capabilities extend equipment life and prevent safety critical failures.

Future development phases will incorporate real time in cabin alert systems, advanced haul road segment analysis with satellite imagery integration, and expanded VHMS parameter integration for tire health and payload optimization. ORAM's scalable architecture positions it for deployment across Tata Steel's raw material operations, establishing new benchmarks for mining safety and operational excellence.