

**MANUSCRIPT TITLE: OPTIMIZATION OF OPEN-PIT MINING OPERATIONS
THROUGH DIGITAL TRANSFORMATION AND IOT INTEGRATION**

Kh. Z. Fayzullaev

Master's Student, Department of Mining Navoi State University

of Mining and Technologies, Uzbekistan

Email: xolbekfayzullayev21@gmail.com



ABSTRACT: Traditional management in open-pit mining faces increasing challenges due to growing pit depth and rising operational costs. This study investigates the integration of Global Navigation Satellite Systems (GNSS), Fleet Management Systems (FMS), and UAV-based 3D modeling to improve operational efficiency. Data were collected over a six-month period to analyze haulage performance. The results show that real-time monitoring increased daily production by 14% and reduced fuel consumption by 8.5%. The study demonstrates that digital transformation significantly improves productivity, reduces equipment downtime, and enhances operational safety in open-pit mining.

Keywords: Smart Mining; IoT; Fleet Management; Open-pit; Optimization.

1. INTRODUCTION. The global mining industry is undergoing a digital revolution. Open-pit mines in Uzbekistan, particularly in the Navoi and Almalyk regions, are reaching

depths exceeding 500 meters, which significantly increases haulage distances and operational costs.. Traditional manual dispatching is no longer sufficient to manage large fleets of 200-ton trucks. The integration of the Internet of Things (IoT) allows for a "connected mine" environment where every asset provides real-time data. This paper explores how digital twins and automated dispatching can optimize these processes.

2. METHODOLOGY

The research methodology involves three integrated layers:

1. **Data Acquisition:** Using UAVs (Drones) to create high-resolution 3D digital terrain models (DTM).
2. **Real-time Tracking:** Installation of IoT sensors on CAT 785C haul trucks and Hitachi EX3600 excavators to monitor cycle times (loading, hauling, dumping, returning).
3. **Optimization Algorithm:** A linear programming model was used to minimize truck queuing time at shovels.

$$T_{cycle} = t_{load} + t_{haul} + t_{dump} + t_{return} + t_{queue}$$

3. RESULTS AND DISCUSSION

The transition from manual to digital dispatching showed significant improvements.

Table 1: Performance Comparison

Metric	Pre-Digitalization	Post-Digitalization	Improvement
Average Cycle Time (min)	48.5	41.2	15%
Shovel Utilization (%)	72%	88%	16%
Fuel Savings (L/ton)	0.85	0.78	8.2%

The use of UAVs allowed for volumetric calculations of rock mass with 98% accuracy compared to traditional surveying, reducing the time required for monthly reconciliation from 3 days to 4 hours. These results indicate that digital fleet management systems significantly reduce idle time and improve coordination between haul trucks and excavators.

4. CONCLUSION. Digital transformation in open-pit mining is not merely a technical upgrade but a structural shift. The findings of this study prove that IoT-based fleet management significantly reduces "bottlenecks" at loading points. For the mining industry in Uzbekistan, adopting these technologies is essential for maintaining global competitiveness. Future work will focus on the integration of Artificial Intelligence (AI) for predictive maintenance of mining machinery. The adoption of digital mining technologies will play a crucial role in improving productivity and sustainability in Uzbekistan's mining sector.

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