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Enhancing Hauling Efficiency in Mining: A Data-Driven Approach to Productivity Optimization

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Introduction

The mining industry is increasingly turning to advanced data analytics to drive operational efficiency and reduce costs in a highly competitive landscape. Hauling productivity, a critical component of mining operations, not only affects immediate operational efficiency but also has a direct impact on overall profitability and production—a key revenue driver.

This study focuses on quantifying the impact of hauling productivity factors by leveraging real-time performance metrics and advanced analytics techniques. Through a detailed analysis of cycle time activities, we identify the primary drivers of both productivity and production. The findings offer actionable insights that can lead to significant operational improvements and enhanced sustainability in mining practices, underscoring the transformative potential of data-driven strategies in modern mining operations.

Objectives

The primary objective of this study is to maximize hauling productivity by optimizing Payload and Cycle Time through advanced analytical models and data-driven methodologies.

Productivity is proportional to the product of Payload and Cycle Time, calculated as follows:

$$\text{Productivity (T/hr)} = \frac{60}{\text{Cycle Time (min)}} \times \text{Payload (T)} \quad (1)$$

Additionally, this study seeks to maximize the production of hauling operations per day, recognizing that this key performance indicator is influenced not only by productivity but also by external factors such as maintenance schedules and operational hours. By addressing both internal and external factors, the study aims to provide actionable insights for improving overall operational efficiency and profitability.

Methods

Key Considerations and Constraints: Reducing cycle time should lead to higher productivity. However, practical constraints such as machine speed, worker efficiency, and operational conditions impose limits on how much cycle time can be reduced. While increasing payload can enhance productivity, excessive payloads may reduce cycle time efficiency, overall operational effectiveness, and compromise safety. Conversely, too low a payload can lead to inefficient and potentially unsafe operations.

This study employs a data-driven approach, analyzing the top 20% and bottom 80% of days in terms of productivity and production from a Nickel mine in New Caledonia over a 3-year period. This approach provides a clear understanding of high and low performance extremes, helping to identify best practices, diagnose issues, focus improvement efforts, and make informed decisions to enhance overall performance.

Sample Data Overview

The table below outlines key metrics for both productivity and production.

Date	Cycles (n)	Production (T)	Productivity (T/hrs)	Cycle Time (min)
2022/02/26	169	16110	187.2	34.7
2023/01/31	58	5382	234.2	27.4
2023/02/21	267	26133	208.4	30.7
2023/08/20	110	10954	226.6	29.2
2024/03/16	246	24242	203.3	30.3

Table 1. Sample data for Hauling Operations

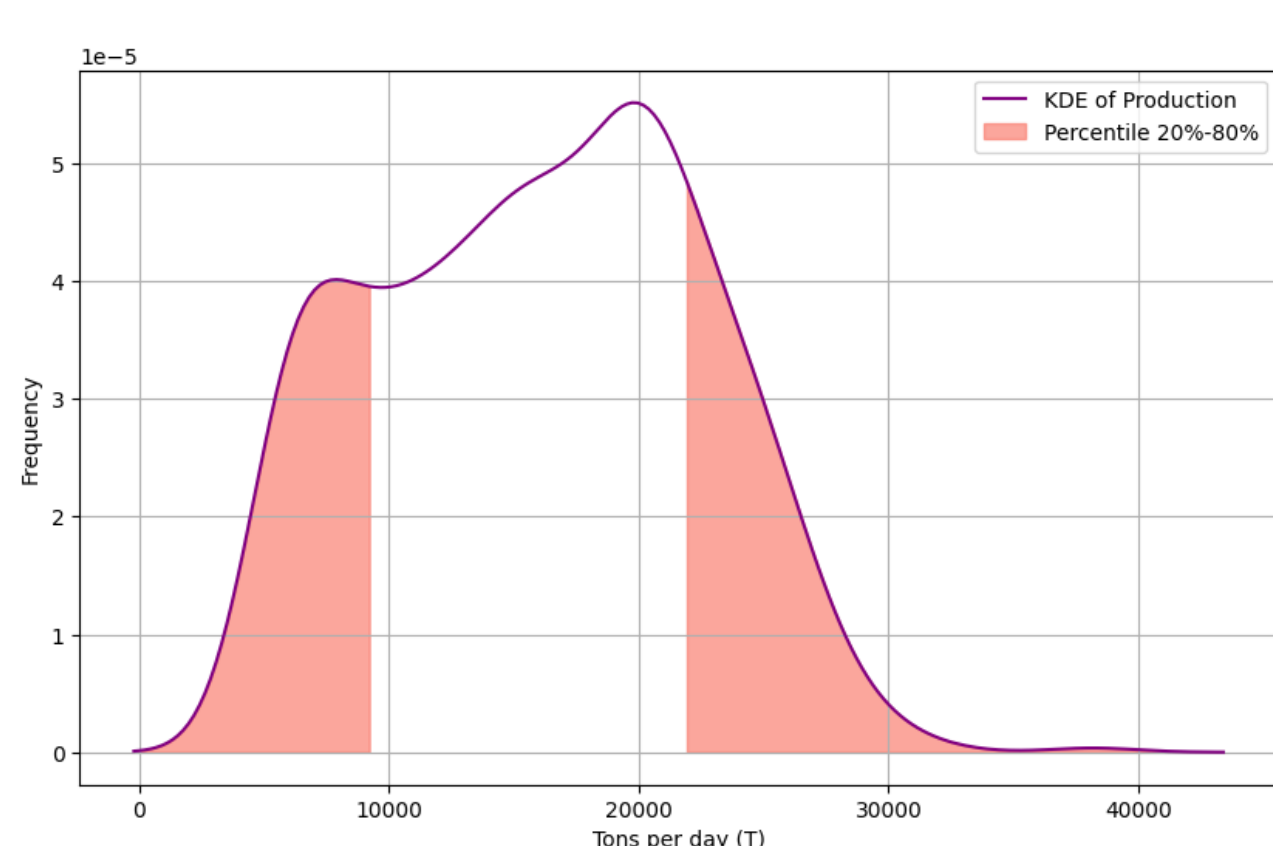


Figure 1. Distribution of production with percentile highlighting

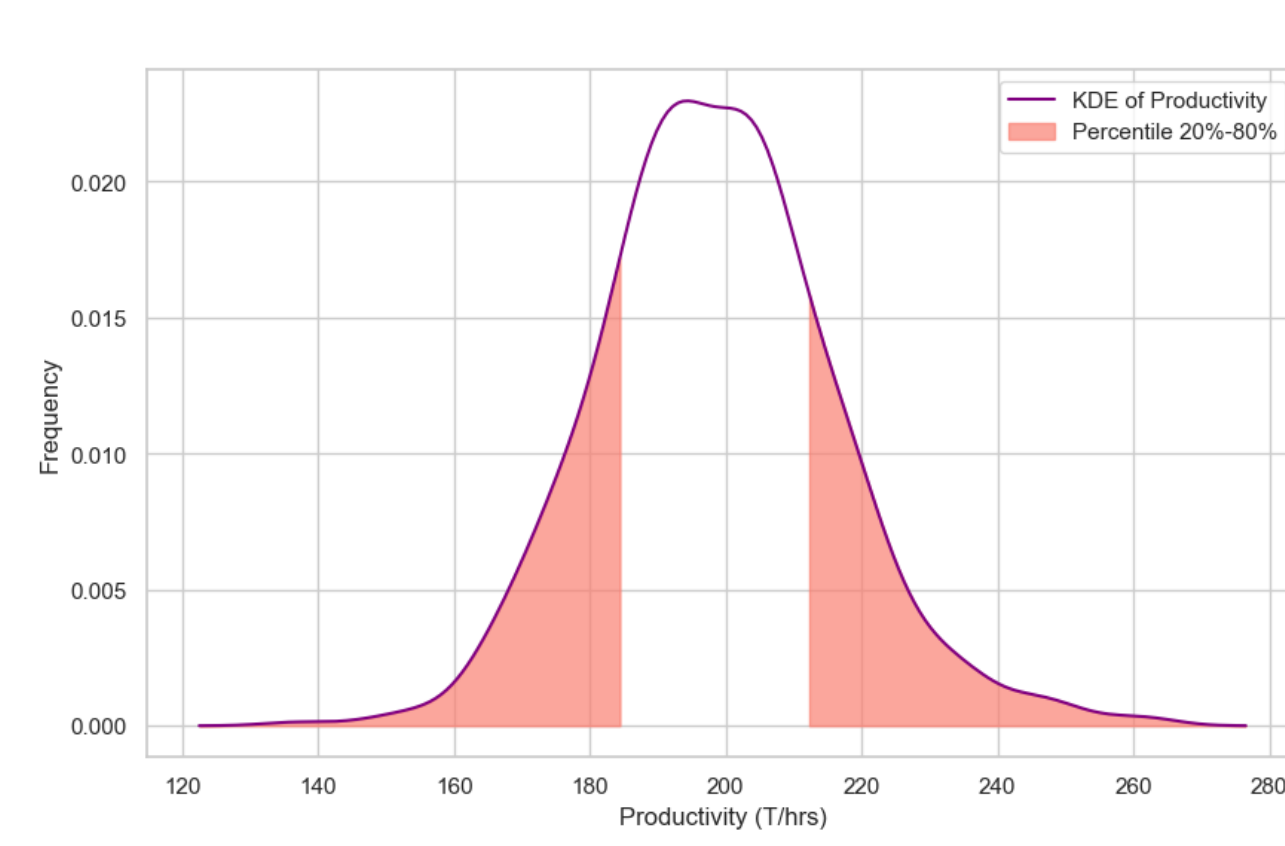


Figure 2. Distribution of productivity with percentile highlighting

Cycle time in mining hauling represents the total time taken for a hauling truck to complete one full hauling cycle. It encompasses all operational activities as shown in figure 3.

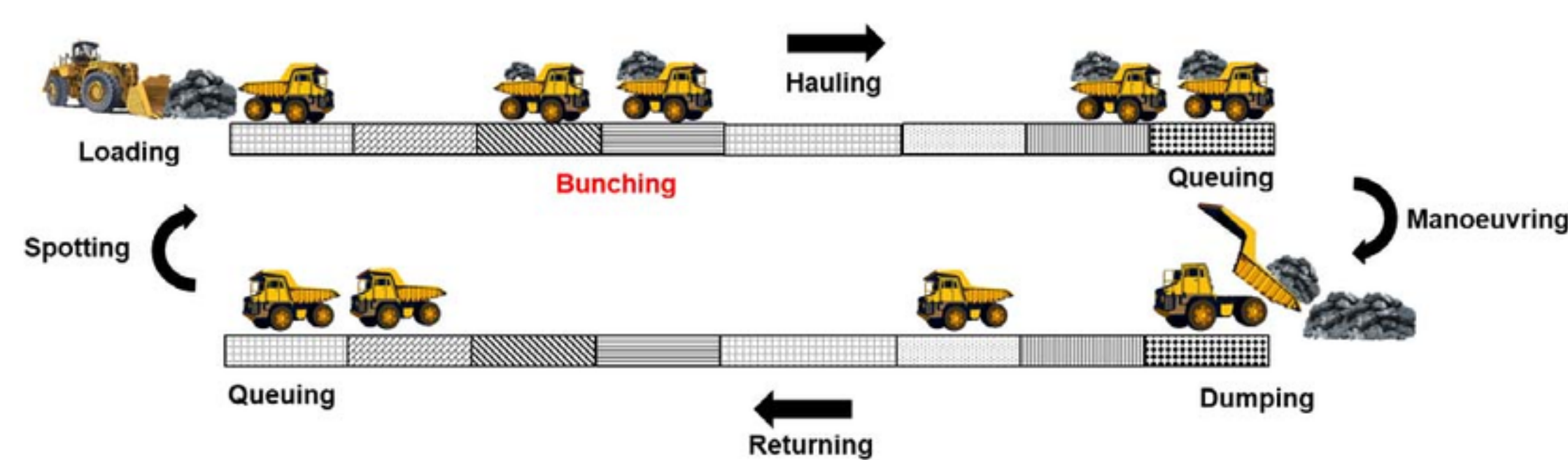


Figure 3. Schematic of hauling operation in surface mines [1]

The cycle time T for a hauling operation can be calculated using the following formula:

$$T = T_{\text{traveling}} + T_{\text{waiting}} + T_{\text{spotting}} + T_{\text{loading}} + T_{\text{manoeuvring}} + T_{\text{dumping}}$$

where:

- $T_{\text{traveling}}$ is the total time a truck spends traveling, including both the empty and loaded portions of the cycle.
- T_{waiting} is the total waiting time, including the time spent waiting at the blast site and at the dump site.

Key Findings

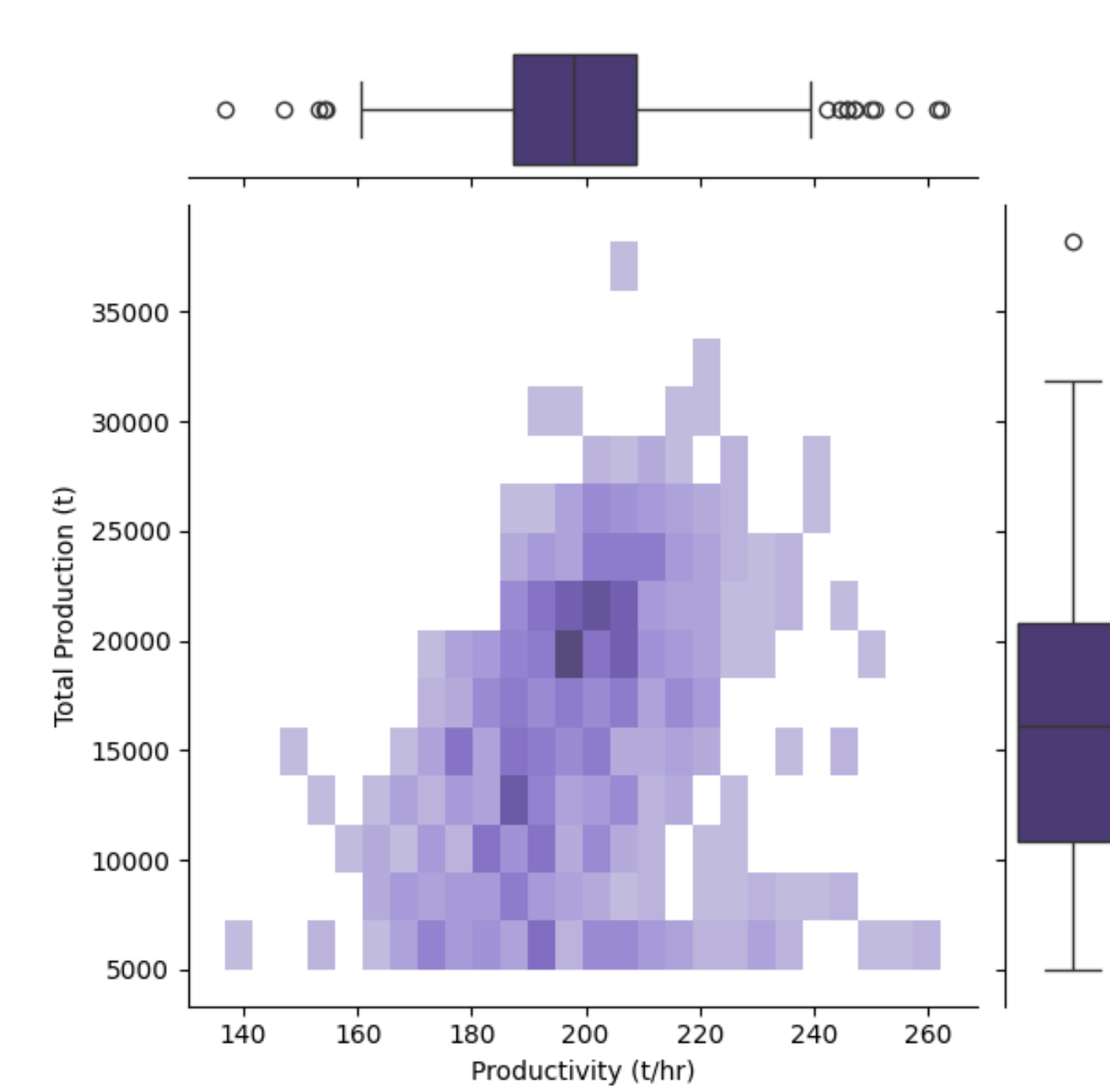


Figure 4. Correlation Between Productivity and Total Production with Marginal Distributions

The chart shows that our best performances in total production do not always correspond to better productivity. With a **Pearson correlation coefficient of 0.29**, the relationship between productivity and total production is weak. This means that factors other than productivity strongly influence total production, indicating that maximizing productivity does not necessarily guarantee maximum production. Having established that productivity alone does not dictate total production, we turn our attention to understanding how the interplay between cycle time and payload influences productivity.

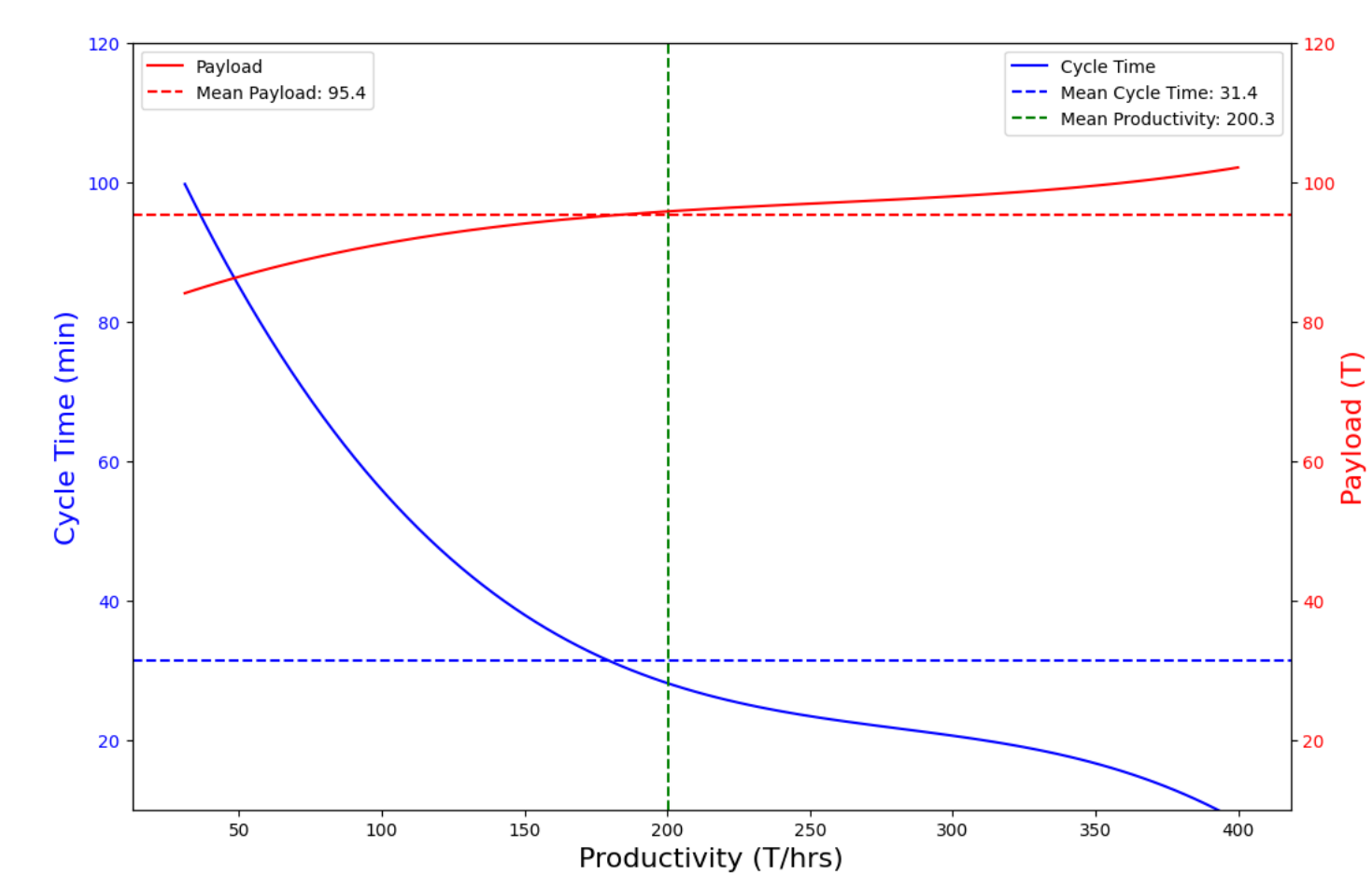


Figure 5. Analyzing the Trade-off Between Cycle Time and Payload in Relation to Productivity

The chart shows that to increase productivity, reducing cycle time is much more effective than increasing the tonnage per truck per cycle. Cycle time decreases rapidly as productivity increases, indicating a strong inverse relationship. In contrast, the tonnage per truck shows only a slight increase with productivity, indicating a much less significant impact, likely due to the minimal variation in payload per cycle.

With a clear understanding that reducing cycle time significantly enhances productivity, it's important to delve into the various time-based metrics of the cycle time and assess how they differentially impact both production and productivity in a combined analysis of our high and low performance extremes for both KPI.

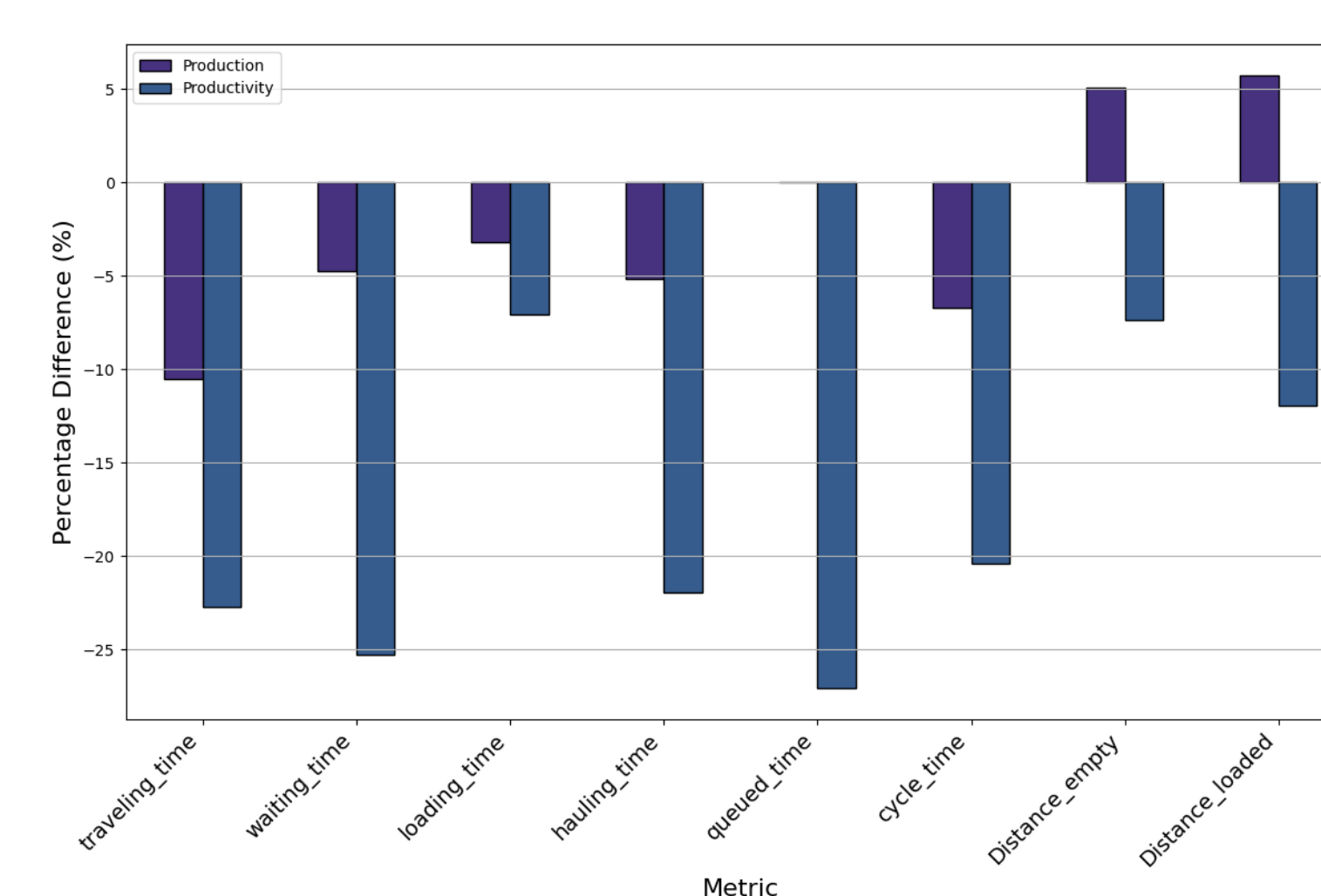


Figure 6. Time-Based Metrics: Their Differential Impact on Production and Productivity

The analysis reveals that although variations in cycle time have a limited impact on total production, they strongly influence productivity. Production fluctuations are mainly due to external factors such as management, operating hours, mechanical failures. Even though travel times have a significant impact on our performance, it's difficult to quantify their potential for optimization due to the differences in distances across the groups. Optimizing waiting times and blast loading and dump is crucial for improving productivity.

Conclusion

This study reveals productivity and production are not as closely correlated as traditionally assumed. While productivity is often seen as a key driver of production, our analysis shows that they are largely independent metrics. The weak correlation between the two suggests that focusing solely on productivity improvements may not yield significant increases in total production.

Instead, our findings underscore the importance of fleet availability and utilization—particularly in maintenance and shift management—as these factors have the most significant impact on production. Future research should prioritize these areas to optimize overall production. Additionally, to enhance productivity, it is essential to refine cycle time metrics. Advanced techniques should be employed to quantify, optimize, and minimize cycle time components, as this has been proven to be the most effective lever for improving productivity.

It is also worth noting that even at our top 80% production days, our productivity is only 5% above the average, further emphasizing that maximizing production requires a broader operational focus beyond just productivity metrics.

Reference

[1] Soofastaei A, Aminossadati S, Kizil MS, Knights P. Simulation of PayloadVariance Effects on Truck Bunching to Minimise Energy Consumption and Greenhouse Gas Emissions. 2015.