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SIMULATING THE ECONOMICS OF AUTONOMOUS HAULAGE FOR MINING TRUCKS

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ABSTRACT

This study evaluates the economics of autonomous haulage systems (AHS), comparing 100-ton rigid haul trucks to 40-ton vocational trucks within a realistic surface mining scenario. The primary objective was to determine the economic viability of using smaller, more cost-effective autonomous trucks versus larger, traditional manned trucks. Smaller trucks are much cheaper to autonomize but are likely to cause congestion, thus lowering outputs and negating unmanned operations' benefits. Simulation was used to model the effects of truck fleet configurations on congestion, queuing, and overall mining rates. The simulation results were used in optimal life-of-mine (LOM) scheduling and net present value (NPV) calculations. The study demonstrated that using autonomous 40-ton trucks improved the mine's NPV by 31% compared to human-driven 100-ton trucks and 7% over autonomous 100-ton trucks. These findings suggest significant potential for cost-optimizing surface mining operations using AHS based on smaller vocational trucks.

1 INTRODUCTION

Mining operations involve complex, interdependent systems with interactive constraints and non-linear dependencies, where decisions on equipment and technology can significantly impact efficiency and profitability. One such decision is the choice between traditional, large haul trucks and smaller, more agile vehicles, especially when considering the implementation of AHS. Although the use of small trucks is uncommon in mining as they have the potential to cause congestion and require more operators, they offer substantial cost savings when implementing AHS.

Pronto AI, an AHS provider, approached Whittle Consulting to quantify the economic impact over the LOM of implementing AHS. The traditional approach to LOM calculations uses linear estimations of mining rates that do not consider the following:

- Queuing of trucks at excavators due to truck-and-shovel pairing
- Queuing of trucks at dumping points due to congestion
- Decrease of haulage speed due to human factors such as breaks and uneven truck speed

Since this study required an accurate representation of the impact of these factors due to changes in fleet size and composition, a more detailed approach was needed. Whittle Consulting approached Amalgama Software Design to use their MineTwin simulation tool to consider these factors and determine the most optimal trucks and shovel fleet configuration. We tested various fleet configurations on three stages of mining: shallow pit (20-68 meters deep), medium pit (116-196 meters deep) and deep pit (244-324 meters deep). The base case mining operation comprised a North American setting, a simple resource model, a three-phase open pit, a site road network and a processing plant.

2 SIMULATION MODEL DEVELOPMENT

Whittle Consulting selected MineTwin OpenPit simulation tool because:

- MineTwin has the basic logic required to replicate open-pit mining operations, including operational scheduling, excavators' relocation, and haulage route calculations.

- Unlike most generic mining software packages, MineTwin allows one to easily extend the basic logic to simulate non-standard aspects like the impact of speed variations due to human factors.
- MineTwin has built-in fleet sizing functionality that varies the number of trucks and excavators and determines the achievable mining rate for each combination.
- MineTwin execution speed is relatively fast, allowing users to run a single scenario of a medium-complex mine within minutes on a standard laptop. It can also be run on a server cluster and multiple experiments in parallel based on the number of available cores.

We created nine scenarios, three for each mining stage, with pit vertical distance ranging from 10 to 324 meters, average haulage distance ranging from 1509 to 4836 meters, and three transportation destinations: crusher, stockpile, and waste storage. For every scenario, we varied the number of trucks and excavators. For the 100-ton truck equipment sets, we varied the number of excavators from 1 to 2 and the number of trucks from 1 to 15. For the 40-ton truck scenarios, we varied the number of excavators from 1 to 10 and the number of trucks from 20 to 90 with a step of 5 trucks. In total, 924 simulation experiments were conducted.

3 RESULTS AND ANALYSIS

For each scenario, we identified the optimal combination of trucks and shovels that minimized time losses due to queuing and congestion, while keeping to the target tons output. The optimal fleet size was then used in the LOM calculations, and the following results were observed.

- **Scenario 1 (baseline)**: The baseline scenario with human-driven 100-ton trucks provided the reference point for NPV comparison.
- **Scenario 2 (autonomous 100-ton Trucks)**: Implementing autonomy in 100-ton trucks resulted in a 23% increase in NPV. The improvement was driven by higher truck utilization and reduced labor costs.
- **Scenario 3 (human-driven 40-ton Trucks)**: Using smaller trucks without autonomy led to a decrease in NPV by 9%, largely due to increased labor costs and congestion, which offset the lower capital and maintenance costs.
- **Scenario 4 (autonomous 40-ton Trucks)**: This scenario produced the highest NPV, with a 31% increase over the baseline. The autonomy significantly reduced labor costs, improved haul speeds, and minimized congestion, making smaller trucks economically viable.

4 CONCLUSIONS

The findings suggest that mining companies should consider the broader implications of adopting smaller autonomous trucks, not only in terms of costs but also their impact on flexibility, scalability, and future technology integration, like electrification. This project also serves as a proof of concept, demonstrating how advanced simulation tools can significantly improve the analysis and optimization of complex mining operations. Future work could explore the scalability of this approach across various mining conditions and the integration of emerging technologies in mining.

REFERENCES

Whittle Consulting, Nick Redwood, 7 August 2023. Whittle Consulting Case Studies. http://https://latestnews.whittleconsulting.com.au/whittle-consulting-pronto-case-study, accessed 20 November 2024.