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HAULAGE SIMULATION WITH COMPLEX ROUTING AND TACTICAL STOCKPILING

Kevin Nguyen
Solene Hegarty-Cremer

Polymathian
76 Ernest St,
South Brisbane
QLD 4101 AUSTRALIA

ABSTRACT

Haulage is typically the largest single cost in open pit mining operations. Small improvements in haulage operations for large open pit mines can translate to significant returns. Delays due to queuing at shovel locations, crushers and dump locations can add up to a significant proportion of the average truck cycle, presenting an opportunity for savings if the causes for queuing can be identified and addressed. Simulation of haulage operations is an essential tool for both understanding the causes for operational delays and testing potential solutions. Simulation of haulage operations requires representation of fundamental truck cycle activities, ancillary activities and movement interactions on complex networks. It also requires simulation of complex decision making if there are many alternative source locations and destinations for different ore types and waste. This presents a challenge for developing a good simulation model representation, but also provides an environment where simulation analysis can deliver significant value.

1 INTRODUCTION

A haulage operation for one of the largest deep open-pit mines in the world uses a fleet of approximately 100 ultra-class haul trucks and 10 shovels with different loading rates at various locations in the open pit. At each location, ore of variable grade and waste is loaded by a shovel and transported to either a crushing station outside the pit, one of a number of ore graded stockpiles for future processing, or one of a number of waste dumps. The haulage requirement is prescribed by a mine plan, which details a mining sequence for each shovel including an amount of each material type to be loaded from specified locations and the required destination for each material type.

Haul trucks are directed to a particular shovel by an automated despatch algorithm, which attempts to maximise haulage throughput, while adhering to the mine plan by minimizing truck queuing. Once allocated to a shovel, a haul truck waits in the loading queue and is loaded by the shovel before moving to the destination for the material type that it was loaded with. After dumping at the required destination, the truck returns to the pit. The shovel allocated to the truck for the next cycle is continually updated in response to changes in the estimated completion time for the trucks currently allocated to each shovel. This is as a result of stochastic load time, positioning time for the trucks and unplanned unproductive time for the shovels. The difference between expected and actual shovel performance, variable interarrival times for trucks entering the pit and time between when a shovel allocation is made and the time that the truck actually presents at the shovel can lead to both queuing of trucks waiting to load and waiting time for shovels with no trucks in the queue.

In addition to productive haulage cycles, haul trucks also undertake non-productive activities including crew breaks, interval maintenance, refueling and have unplanned breakdowns. Staggered shift changes require approximately half the haul truck fleet to park up at a time at designated locations on the haulage network.

In addition to two dump pockets for tipping directly to the crushing station, there are also "dump and run" stockpiles. These are single truck dump locations near the crusher that can be used to alleviate short term queuing for the crushing station, but require a loader to rehandle the ore to the crusher.

The presentation sequence of trucks with varying ore attributes can also have a significant effect on downstream performance, so in addition to timing, there can also be value in manipulating the presentation sequence to improve ore delivery. Larger tactical stockpiles in the vicinity of the crushing station can also be used to manage the presentation of ore grade to the crusher over time, but require rehandling by loader and truck at additional operating cost.

2 SIMULATION MODEL OVERVIEW

The simulation model representation of the haulage operations was developed with the intention of providing realistic timing of each productive truck cycles as well as truck ancillary activities. Truck movements are based on a path network including representation of haulage routes, loading and dumping locations and various routes through the crushing station. Occupation of paths in the haulage network is controlled to manage interactions between trucks and prevent network lockups. While much of the haulage network is bidirectional, vehicle interactions are managed at haulage network intersections and at loading locations and the crushing station, which have single direction paths. Following distance is also managed for both moving an stationary vehicles.

Equipment performance characteristics are modelled, such as acceleration, speed, deceleration and payload to align modelled operations with historical performance. Simulation of truck movement on the haulage network is integrated with a representation of shovel and crushing station performance, as well as shift changeover and ancillary activities such as maintenance, refueling and unplanned outages.

The model is data driven and enables changes to the mine plan, haulage network, equipment type, fleet size and operational methodology. This allows testing of haulage operations through different stages in the mine life.

3 ANALYSIS OUTCOMES

Simulation of the haulage operations produced similar periodic queuing at the crushing station and shovels as observed in historical operations data, which were caused by shift changes and persisted through the shift. Use of tactical stockpiles, changes in allocation logic for trucks to shovels and modification to shift change procedures were investigated as a means of reducing delays due to truck queuing and improving overall performance of the haulage operations. Alternative strategies were also tested to improve the sequence of ore presentation to the crusher based of the ore attributes for each truck enroute to the crushing station. These strategies included selection of trucks to dump at tactical stockpiles rather than directly into the crusher.

Haulage performance and ore presentation results developed using the simulation model have been used to identify opportunities for improvements for the haulage operation. These improvements include potential changes truck to shovel allocation procedures and strategies for use of "dump and run" and tactical stockpiles to reduce queuing a the crushing station and improve ore presentation.