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APPLICATION OF SIMULATION OPTIMIZATION TO MINIMIZE DOWNTIME

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ABSTRACT

In this case study, simulation optimization is used to minimize the inventory required to meet a target level of unplanned outage time (or conversely, minimize the cost of downtime for a given inventory level). A large inventory of conveyor belts is maintained as insurance stock to minimize the cost of downtime associated with a conveyor belt failures. Hundreds of conveyors are used across multiple sites, each with a different probability and cost of failure. A MIP formulation is used to optimize inventory holdings for each belt material type. Conveyor belt failures are then simulated over a long period of operations to provide an assessment of the likely range of performance for the optimized conveyor belt inventory and comparison with the existing inventory. The study provides a relatively simple application of simulation optimization that has the potential to deliver significant value to operations with large spare parts inventory holdings.

1 INTRODUCTION

Operating in Western Australia's resource-rich Pilbara region, a major iron ore producer maintains an extensive network of conveyors across multiple sites at both mine and port locations. The total number of conveyors across all sites is approximately 600 and the conveyor belts range in length from a few hundred meters to 20 kilometers. Conveyor availability and reliability plays a crucial role in achieving production targets and company profitability.

When a belt wears thin or tears, requiring replacement outside normal replacement intervals, the time taken to get operations back online depends on how quickly that belt (in whole or in part) can be replaced. Every hour that the conveyor is off-line can translate to thousands of tonnes of lost iron ore production. Ordering a replacement belt after a breakdown occurs is not acceptable, as delivery can take up to four months. Instead, a safety stock of belts is held for both planned and emergency maintenance. Since the belts that make up the transport system are of varying widths, thickness and other specifications, the amount of safety stock is considerable, and costs into the hundreds of millions of dollars.

Different belts move iron ore at difference rates and at different utilization levels. In terms of operational downtime, delays for delivery of replacement belts for some conveyor belts are more costly than others. To balance the cost of inventory holding and loss of productive revenue due to conveyor belt failures, the producer needed a way to be certain they were carrying the right type and amount of inventory.

2 SIMULATION MODEL OVERVIEW

A simulation model was developed to sample conveyor belt failure frequency and type of failure based on historical data. Historical records of conveyor failures provided observations of belt tears or accelerated wear. For accelerated wear observations, (estimated) time until replacement to avoid conveyor downtime was provided.

Initial conveyor belt inventory was used as a model input for the start of each simulation run. Reordering logic with lead times by belt material type and length for delivery and ordering policies was used to maintain the conveyor inventory at prescribed levels. Some belt materials (with different costs per unit length) could be used as a substitute for others according to defined hierarchies.

A Mixed Integer Programming (MIP) formulation for the conveyor failure problem was developed and solved to minimize the cost due to downtime as a result of conveyor failures for a given belt inventory holding budget. The optimization step provides a recommended conveyor belt inventory profile for a set of model inputs including conveyor failure rates, cost profile for each hour of downtime and belt material substitution hierarchy.

The simulation model was used to evaluate the long term average cost due to conveyor downtime for a particular (target) conveyor belt insurance inventory profile Inputs for the simulation model including conveyor failure rate distributions, downtime cost profiles and belt substitution details were the same as those used for the optimization step. Detailed results, such as aggregate holding costs and downtime for each belt material type were produced by the model to allow evaluation of the long-term average performance of alternative insurance stock profiles and the potential range of costs for conveyor downtime.

The simulation optimization model was deployed to the iron-ore producer, allowing reassessment of the conveyor belt inventory as more conveyor failure data becomes available and/or system parameters, such as belt material costs, lead times to replenish belt material stocks and suppliers change.

3 ANALYSIS OUTCOMES

The simulation model was first run using the existing conveyor belt insurance inventory profile. Multiple replications were run with the simulation model to assess the long term average cost and potential cost range for conveyor downtime. The simulation model was then run with the recommended (optimized) inventory profile to develop a comparative cost for long term average downtime due to conveyor failures.

By changing the inventory budget and developing an optimized conveyor belt inventory at each cost point, a relationship between inventory budget and risk, (or long term average cost of downtime due to failures and accelerated wear of conveyors) was developed. The relationship was used to identify ideal insurance stock levels to minimize overall cost to the business.

A 30% reduction in long term average costs due to conveyor downtime for the optimized inventory profile compared with the existing conveyor belt insurance inventory profile was observed.

Simulation analysis was also used to demonstrate that by increasing the inventory budget by 15 percent, a risk reduction (long term average cost due to downtime) of nearly 50 percent could be achieved. These data-supported findings were used to support a case for increasing the warehousing and safety stock budget, with significant long-term average cost savings due to reduced downtime for conveyor belt replacements following failures.