Consumable Costing Review With Relation To Mining Conditions

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Abstract

Downer EDI Mining is a leading provider of contract mining equipment and services throughout Australia and the Asia Pacific region. Their business' profitability and reputation depend greatly on their ability to accurately estimate the cost of running their fleet and delivering services to their clients. This project utilises historical cost data from Downer EDI Mining to produce cost profiles and models for their mining equipment consumables which include buckets and bodies (B&B) and ground engaging tools (GET). Such models are used by estimators to produce tenders and predict future costs in running their fleet. An investigation is also made into the factors that contribute to the wear and subsequent costs of consumables. Findings suggest that the wear and costs of most mining equipment consumables are related to their size. In some cases there was also a significant correlation to the number of hours of work, suggesting that older machines tend to incur higher costs. Finally, it was also found that equipment subject to intense exposure with abrasive material have GET costs related to the abrasion index of the material.

1. Introduction

Possessing an accurate set of cost-profiles and models for their assets is of great commercial benefit to Downer EDI Mining as the more accurately their estimators can predict costs, the more competitive and profitable they are as a company. This project utilises historical data from Downer EDI Mining to produce cost profiles and models for their mining equipment consumables. The consumables include buckets and bodies (B&B) and ground engaging tools (GET). This review also attempts to relate the costs of mining equipment consumables to operating conditions and various equipment characteristics such as size and work hours.

Buckets and bodies are the foundations of mining equipment such as trucks and excavators. The costs incurred in B&B are often related to maintenance activities such as welding in steel plates and crack repairs. Ground engaging tools are used to physically penetrate the ground and prevent damage to more expensive components of earth-moving equipment. These tools are designed for high abrasion resistance and include parts such as shovel teeth, cutting edges, wing and lip shrouds.

1.1 Review History

There are many methods to predict the costs of running a fleet of mining equipment. Downer EDI Mining does this by tracking the actual costs of running their fleet in the field and applying this knowledge to their future tenders and estimates. The company has been working annually with CEED students from Australian universities since 2001 to produce up-to-date cost profiles for all of their equipment based on their historical field data.

The work completed by students in previous years has focused on producing cost models for minor parts and labour rates. Each year's work advances the state of art by producing more accurate cost profiles which include the company's latest data and technical improvements. This review goes even further as it is the first time that Downer EDI Mining's B&B and GET consumables will be properly reviewed and modelled. It is also the first time that an investigation is made into the relationship between the client's equipment costs and the conditions which they operate in.

The previous reviews completed for Downer EDI Mining have established and refined the procedures for obtaining and processing raw data and developing cost profiles. However, as this is the first time that a review has considered the client's mining consumables, the procedures were modified to suit the different data set.

2. Methodology

2.1 Data Retrieval and Processing

All of Downer EDI Mining's historical cost data is captured and stored within their in-house business software. The cost data was downloaded via this software then imported and formatted into Excel workbooks, with a separate workbook for each class of the client's assets. These asset classes are dozers, draglines, excavators, graders, trucks, water carts and wheel loaders.

The first step to processing the data was sanitisation. Due to the large amount of data across the client's fleet, it was not uncommon for errors to be recorded into their system. For accurate cost profiles and models to be produced, these had to be identified and rectified. A method of error-searching and rectification was developed through the use of Really Real Time Reports. These are large spread sheets containing data for every dollar the company has spent on B&B and GET over a period of time. They could be filtered to show the data for a particular asset over a designated time period, so as to identify where each dollar was spent over that period.

Anomalous-looking entries were checked against the relevant reports to identify any errors that may exist. If an error was found, the entry was modified and a comment was inserted into the cell specifying the change made. If it was found that no error existed, a comment was inserted to inform future users that the cell had been checked. The sanitisation process was a time-consuming one which required approximately 142,500 data entries to be checked.

The next step taken to process Downer EDI Mining's data was cost escalation. Using historical costs as the basis of future estimations is only useful if the effect of time is accounted for. The prices of parts and components change over time due to a number of factors such as the change in strength of the Australian dollar, economic conditions, the availability of materials and labour, and market competition. In order to produce accurate cost profiles for use by the client's estimators, it was necessary to account for the yearly changes in cost by escalating historical cost data to today's value. A favoured method in doing so amongst planners and estimators is through the use of cost indexes (Remer and Mattos, 2003).

A cost index is a dimensionless number used to compare cost changes between periods for a fixed quantity of goods. Its use is desirable as it allows for estimations of similar costs from past to present periods without the need to complete a detail cost analysis (Dhillon, 2010). The use of cost indexes for converting costs between time periods may best be represented by Equation 1.1.

$$\boldsymbol{C_c = C_r\left(\frac{I_c}{I_r}\right)} \tag{1.1}$$

Where **C_c is the desired cost, present, future or past in dollars**
C_r is the reference cost in dollars
I_c is the index chosen to correspond to time period of C_c
I_r is the index chosen to correspond to time period of C_r

Cost escalation indexes were produced for each year based-off a correlation between Original Equipment Manufacturer (OEM) parts prices and Producer Price Indexes (PPI) from the Australian Bureau of Statistics. It was found in previous reviews that OEM prices accurately reflected the costs paid by Downer EDI Mining and that a strong correlation could be found with certain PPI sets related to the mining and metallurgy industries (Saleh, 2010). Having produced these yearly escalation indexes for B&B and GET costs, they were applied to the sanitised cost data for profiling and modelling.

2.2 Profiling and Modelling

The cost profiling stage is arguably the most economically important phase of this review as it results in the production of values that may be used by the client for predicting the future costs of running their fleet. Downer EDI Mining's estimators require profiles in the form of average dollar per hour rates for each type of asset in a variety of operating environments. Once these rates are checked and approved by senior estimators they are implemented into the company's Plant Estimating Software to predict the future costs of running similar equipment.

Rates were developed through the use of Excel pivot tables which have the ability to sum and organise copious amounts of data into a simple table. Data reliability was assessed by the number of assets contributing to a cost rate and the number of hours they had worked in that environment. They were assigned confidence levels based-off reference values specified by Downer EDI Mining.

Following the completion of cost profiling, models were produced to investigate factors that contribute to the wear of consumables and their costs. Models were made in the same Excel workbooks using pivot charts and statistical analysis functions. Where significant correlations were found, it was possible to produce formulas that may be used as predictive tools given certain parameters. The parameters modelled against included operating conditions and equipment characteristics including size and work hours.

A relevant study completed in 2010 attempted to find a correlation between operating conditions and excavator tooth consumption rates for the Newmont Mining Corporation's GET. The study found that "there is no single index that can provide a measure of the abrasiveness of a rock sample…more confident predictions can be made by the use of a wide range of tests and examinations." (Roos et al. 2010). One relevant index is the Bond Abrasion Index (AI) of an ore. Numerous sources have stated that the AI is a suitable index for modelling against tool costs and wear rates, but it is often difficult to come by due to its test's expensiveness in cost and time. Consequently, it was decided to also search for and test another ore parameter; the Unconfined Compressive Strength (UCS) which is more readily available.

As Downer EDI Mining have not yet completed any reviews that model operating conditions, they possess very little of the data in-house. As such, the operating condition data had to be obtained via external contacts and sources. This was a difficult task as legalities prohibited contacts from providing such information due to confidentiality restrictions. Of all the sites Downer EDI has historical cost data for, operating condition data was obtained for a total of 40% of them.

3. Results and Discussion

Through the methodology described, it was possible to produce a comprehensive set of cost profiles for the client's B&B and GET consumables. An analysis of the profiles found that there was little correlation between GET and B&B costs across all asset classes, suggesting that the two different consumables wear according to different criteria. It is hypothesised that this is due to their respective designs and purposes.

GET are made to undertake the most intense abrasive wear in order to protect more expensive parts including blades, buckets and ripper shanks from highly abrasive materials. B&B are designed to handle similar abrasion but due to their function, they are also subject to impact from large rocks and ore. The size of rock and ore is greatly dependent on the initial drilling and blasting completed prior to excavation. As such, B&B rates differ from GET rates due to the existence of material which can cause impact stress and wear to the equipment.

Models were produced to determine the relationships that exist between consumable costs and machine characteristics including size and hours of service. In general, it was found that assets in the excavator, grader, truck and wheel loader classes had consumable costs with medium to high correlations to the machine weights. In particular, trucks and wheel loaders showed 99.8% and 96% correlations in B&B costs respectively. These trends are shown visually in Figure 1. Such high correlations suggest that larger machinery (in these particular classes) do indeed have higher consumable costs than their smaller counterparts.

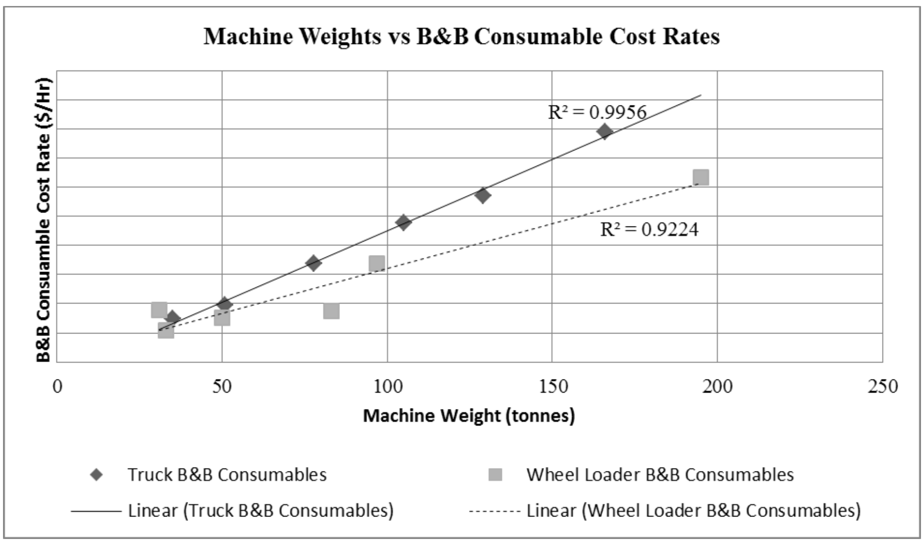

Figure 1 Model showing the relationship between machine weights and B&B consumable cost rates for trucks and wheel loaders

There are many potential explanations for this occurrence; it may be due to the size of the equipment resulting in more damage and repair costs, the ability to carry greater loads which inflict higher stresses, or the nature of the repairs being more costly for larger machines. Such high correlations allowed for the relationships to be modelled by equations that may be used by estimators for predicting consumable costs based on known machine size. However, it should be noted that attempting to predict the cost of a new or foreign type of machinery using a model based-off other types may result in inaccuracies.

Models were also produced to investigate the relationship between working hours and consumable costs for each of the asset classes. It was found that the only asset classes with a reasonably strong correlation were trucks and water carts whose correlations with B&B costs were 75% and 73% respectively. This can be explained by a number of factors such as the tendency for older equipment to fail more often, potentially greater costs incurred in fixing older bodies, or even the change in operating conditions over time which could result in more intense wear on B&B.

Modelling against the Bond Abrasion Index found that most assets used in direct contact with rock, ore and coal had a medium to high correlation between their GET costs and the AI of the material mined. The index was developed to measure of the abrasiveness of a sample, thus it was expected that those with higher AI values would cause significantly more wear on GET, subsequently incurring a greater cost. In the excavator and dozer classes, the correlations between GET costs and AI were 85% and 95% respectively. These trends are shown visually in Figure 2. Equations were made that quantify these correlations for use by estimators as a tool to predict GET costs based-off known AI values.

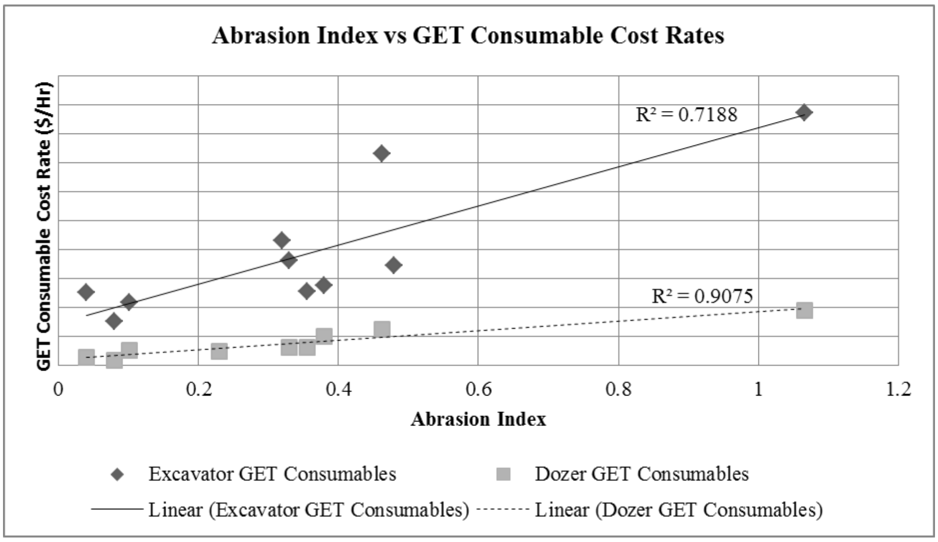

Figure 2 Model showing the relationship between abrasion index and GET consumable cost rates for excavators and dozers

Similar equations could not be made for the relationship between AI and costs in the other five asset classes as there was either insufficient operating condition data or the correlations were too low. In the latter case, the result suggested that AI had little effect on the costs incurred by GET. It was deduced that this was the case for assets which are not subject to intense exposure of abrasive material as they would wear according to other factors such as the machine characteristics or material size.

Models were also produced in an attempt to find a relationship between consumable cost rates and the UCS of ore. It was found that little correlation existed in every asset class. This suggests that the UCS of ore has little to no influence on the rate at which consumables wear and their subsequent costs. As UCS is a measurement of the cohesiveness of a material sample, it is deduced that the measurement had little correlation due to the fact that most of the materials in contact with Downer EDI's fleet had already been blasted. Thus the UCS is of little relevance when discussing the movement of materials by equipment such as excavators, dozers and trucks in a drill and blast mining operation.

4. Conclusions and Future Work

The cost profiles produced are adequate for use by Downer EDI Mining estimators in predicting the costs of earth-moving consumables. They are of great economic value to the client and it is recommended that yearly reviews be continued using the same methodology so as to update the figures with the latest cost data. The effects of sanitisation and escalation were explored and deemed to be vital to the production of a set of accurate figures. The implementation of a set of confidence criteria allows estimators to use the profiles at their own discretion with confidence in the reliability of their predictions.

An investigation was made into factors that contribute to wear of the consumables and subsequent costs. It was found that the costs of most mining equipment consumables are related to their size. However, findings also suggest that the costs of equipment in the different asset classes could be related to other factors such as hours of work. It is recommended that future reviews perform a time-based analysis on these classes to ascertain the nature of the result. Such an investigation may also be able to uncover the optimal replacement time for consumables, saving Downer EDI considerable maintenance costs in failing equipment.

It was also found that equipment subject to intense exposure with abrasive material, such as excavators and dozers have GET costs related to the abrasion index of the material. Where the correlation was high enough, the relationships found were quantified by equations that can be used to predict costs or produce estimates. In future reviews it is recommended that the operating condition values be obtained at the start of the review and that values for new projects undertaken by Downer EDI Mining are requested in future tenders.

5. References

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