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Hard-rock LHD cost estimation using single and multiple regressions based on principal component analysis

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ABSTRACT

In feasibility studies and mine planning, accurate and effective tools and methods facilitating cost estimation play an important role. Load–Haul–Dump (LHD) machines are a key loading and haulage equipment in most of the underground metal mines and hard rock tunnels. In this paper, a cost estimation model of these vehicles has been presented in the form of single and multivariable functions. These functions have been provided on the basis of costs types (i.e. capital and operating costs) and motor types (diesel and electric). Independent variables, in the single regression analysis is bucket capacity and in Multiple Linear Regression (MLR) analysis include bucket capacity, overall width, overall machine height and horse power (HP). The MLR is conducted in three steps. First, with the help of Principal Component Analysis (PCA), correlation between independent variables is omitted. Thereafter, significant PCs are selected and used as independent variables in the MLR functions. Finally, the cost relationships are established as functions of initial LHD variables. The mean absolute error rates are 11.59% and 6.87% for the single and multiple linear regression functions, respectively.

1. Introduction

The feasibility studies require in-depth analysis that involves a review of different technical, economic and operational aspects of each project and the selection of the most appropriate alternative accordingly to the chosen criteria. Process determination, equipment selection and costs–revenues estimation are principal parts of these studies. Cost estimation with different purposes take place at different stages of a project. During the planning stage, cost estimates are used to determine project feasibility and compare alternate modes (Romero and Stolz, 2002). At this stage, machine specifications like technical and operating features and costs especially operating costs data, are not available in the mineral fields unlike other areas (Mutmansky et al., 1992). With this view, developing an up-to-date model with sufficient accuracy is essential for the cost estimation of equipments.

Loading and hauling are among the most crucial operation impacting production in surface and underground mines and have a substantial share of a total mine costs. Load–Haul–Dump (LHD) machines are the most common equipment used to, as their name implies, load and haul rock material in underground mines and hard rock tunnels. LHD vehicles are typically used to load ore at the draw points or in the stopes and haul it to dumping points (Larsson et al., 2005). When a haulage distance becomes too long, LHDs usually dump the muck into mine trucks. The important advantages of using LHDs are their suitable loading and hauling capabilities, high mobility and operational flexibility.

Different tools can be used in order to develop the cost estimation models, hence; one can point out to the linear and non-linear regression models, techniques related to fuzzy logic and artificial intelligence like neural network (Cavalieri et al., 2004). Application of different cost estimation tools has showed that professional cost estimators usually use regression to build their cost models (Mason and Smith, 1997).

So far, a number of cost models using the Single Regression Analysis (SRA), for the estimation of mineral industry costs, have been published. Hence; one can point to the estimation of mining and mineral processing equipment costs and capital expenditures (Mular, 1982; Mular and Poulin, 1998), estimation of preproduction and operating costs of small underground deposits (Canmet, 1986), capital and operating cost estimating system for mining and beneficiations of metallic and nonmetallic minerals in the United States and Canada (USBM, 1987), cost estimation for the Australian mining industry (Lanz and Noakes, 1993), quick guide to the evaluation of ore bodies (O'Hara, 1980, 1982, 1987; O'Hara and Suboleski, 1992), simplified cost models for prefeasibility mineral evaluations (Camm, 1994), Australian mining and energy valuation for investors and management (Rudenno, 1998). These

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cost estimating systems utilized a generalized approach based on the exponential regression function. Some of these models have become obsolete and updating them may cause substantial errors. On the other hand, as the capital or operating cost models are univariate, the role of other effective independent variables has simply been ignored. Multivariable cost estimation models, on the basis of up-to-date data, would remedy these shortcomings. In this study, the Multiple Linear Regression (MLR) method and the Principal Component Analysis (PCA) are combined to obtain an estimation model for costs of hard rock LHD machines. These functions have been provided on the basis of costs types (i.e. capital and operating costs) and motor types (diesel and electric). It should be noted that operational cost estimation is of the major importance, because the required data are not simply available in the feasibility stage of operation. Moreover, large disparities can exist between prices estimated and those actually charged to a specific buyer. These disparities are related to the business policy of the manufacturer, its policy towards current or new customers, the differences in specific options added, etc.

2. Data

Sixteen different sizes of LHDs (11 diesel-powered and 6 electric machines) were considered and a set of technical and economic data from USA equipment manufacturers, mining companies and projects has been gathered (InfoMine, 2010) (Fig. 1). The capital cost is based on US dollar (2010) while the operation cost is based on US dollar (2010) per hour. Economic data are collected by surveys of equipment manufacturers and distributors; energy, tire, fuel and lubricant suppliers; and US mining companies. The data are classified on the basis of cost types (capital or operating) and motor types (diesel or electric). The operating costs items include: overhaul (parts and labor), maintenance (parts and labor), fuel (or power), lubrication, tires and wear parts. The cost of operator's time is not included here. Fig. 2 shows the relative contribution of each of these items, based on the gathered data sets. Accordingly to the source data, maintenance and wear parts items account for the highest and the lowest shares, respectively.

In this study, LHD overall width (OW) in meter, overall machine height (OH) in meter, horse power (HP) in horse power and bucket capacity (BC) in cubic meter are independent variables in MLR and bucket capacity in SVA. Descriptions of data related to each of these variables are shown on Table 1. Also, the normal distribution of data has been approved.

The data analyses show an intense correlation between independent variables (Table 2). Thus, it is necessary to take this aspect into consideration while analyzing the multiple variables (Gujarati, 2003).

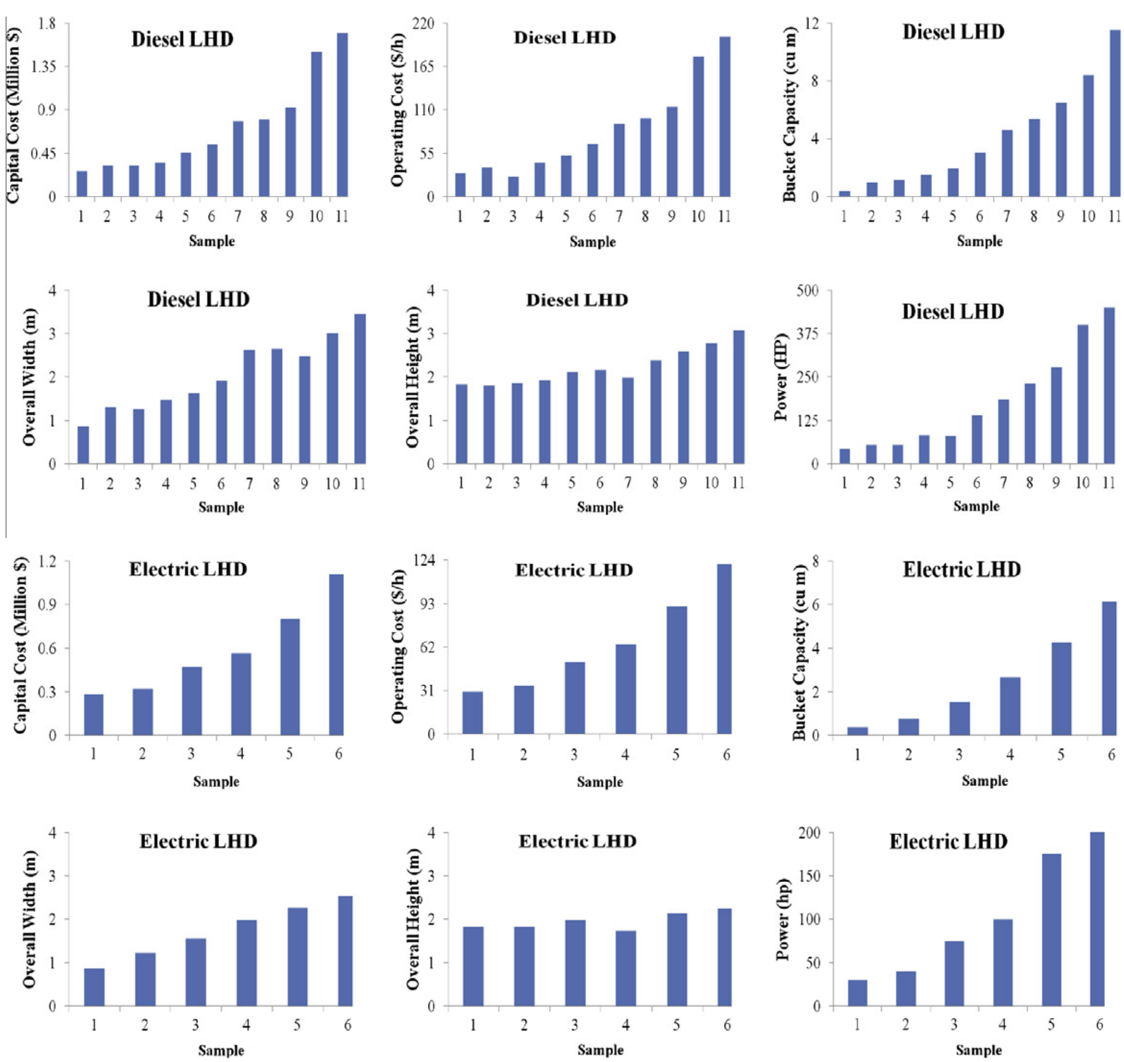

Fig. 1. Data sample considered in research.