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Application of analytical hierarchy process to selection of primary crusher

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ABSTRACT

Selection of crusher required a great deal of design based on the mining plan and operation input. Selection of the best primary crusher from all of available primary crushers is a **M**ulti-**C**riterion **D**ecision **M**aking (MCDM) problem. In this paper, the **A**nalytical **H**ierarchy **P**rocess (AHP) method was used to selection of the best primary crusher for Golegohar Iron Mine in Iran. For this reason, gyratory, double toggle jaw, single toggle jaw, high speed roll crusher, low speed sizer, impactor, hammer mill and feeder breaker crushers were considered as alternatives and capacity, feed size, product size, rock compressive strength, abrasion index and mobility of crusher were considered as criteria. As a result of our study, the gyratory crusher was offered as the best primary crusher for the studied mine.
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1. Introduction

The primary crusher selection is the key to the success of the mining, quarry or industrial mineral operation that involves the reduction in the size of rock, ore or material. The crushing equipment standard to the mineral industries has been gyratory, double toggle jaw, single toggle jaw, high speed roll, low speed sizer, impactor, hammer mill and feeder breaker. There were advantages and disadvantages for any crusher, so that the selection of suitable primary crusher is a multi-criteria decision making (MCDM) problem. Analytic hierarchy process is a well-known method for solving decision-making problems. In that method, pairwise comparisons are performed by the decision-maker (DM) and then the pairwise comparison matrix and the eigenvector are derived to specify the weights of each parameter in the problem. The weights guide the DM in choosing the superior alternative [1]. This method has been used for a variety of specific application in decision making problem such as equipment selection in open pit mining, selection of optimal reclamation method, rock mass rating, tailing dam site selection, underground mining method selection, selection of optimum mining method, Choosing shaft sinking method, Determining proper strategies for dimensional stone mines, equipment selection and selection of material handling equipment system [2-12]; however, its application in primary crusher selection has not been reported yet.In this paper, **A**nalytical **H**ierarchy **P**rocess (AHP) was used for primary crusher selection for Golegohar Iron Mine in Iran. For this purpose, capacity, feed size, product size, rock compressive strength, abrasion index and application of primary crusher for mobile plants have conceded as important criteria.

2. Analytic Hierarchy Process (AHP)

The AHP is based on the innate human ability to make sound judgments about small problems. This method was first presented by Saaty [13]. It facilitates decision-making by organizing perceptions, feelings, judgments and memories into a framework that exhibits the forces that influence a decision. The AHP is normally implemented in conjunction with the use of expert choice and it has been applied in a variety of decisions and planning projects in nearly 20 countries Saaty in 1990. Briefly, the step-by-step procedure involved in using the AHP is as follows:

Step 1

In the first step the hierarchy is structured on different levels: from the top (i.e. the overall objective), through intermediate levels (the criteria and sub criteria on which subsequent levels depend), to the lowest level (i.e. the alternatives).

Step 2

Weigh the criteria, sub criteria and alternatives as a function of their importance in relation to the corresponding element on the

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higher level. For this purpose, the AHP uses simple pair wise comparisons to determine weights and ratings so that the analyst can concentrate on just two factors at a time. Verbal judgments are then translated into a score using discrete 9-point scales; let a represent an $n \times n$ pair-wise comparison matrix.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}$$

The diagonal elements in the matrix A are self-compared of the alternatives, and thus $a_{ij} = 1$, where $i = j$, $i, j = 1, 2, \ldots, n$. The values on the left and right sides of the matrix diagonal represent the strength of the relative importance degree of the ith element compared to the jth element. Let $a_{ij} = 1/a_{ji}$, where $a_{ij} > 0$, $i \neq j$.

Step 3

Once the judgment matrix has been developed calculate a priority vector to weigh the elements in the matrix. This is the normalized Eigen vector of the matrix. The normalization of the geometric mean method is used to determine the importance degrees of criteria. Let w_i denote the importance degree for the ith criteria, then [14]:

$$w_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}} \quad i, j = 1, 2, \dots, n \tag{1}$$

Step 4

Test the consistency of the importance degrees of criteria. To ensure that the evaluation of the pair-wise comparison matrix is reasonable and acceptable, a consistency check is performed. Let c denote an n-dimensional column vector describing the sum of the weighted values for the importance degrees of criteria, then [15]:

$$c = [c_i] = A.W^T_{n\times 1}, \quad i = 1, 2, \dots, n \tag{2}$$

where

$$A.W^T = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \cdot [w_1, \quad w_2, \quad \dots, \quad w_n]^T = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix}$$

The consistency values for the cluster of criteria can be represented by the vector $CV = [cv]_{n\times 1}$ with a typical element cv_i defined as [16]:

$$cv_i = \frac{c_i}{w_i}, \quad i = 1, 2, \dots, n \tag{3}$$

However, to avoid the inconsistency occur when using different measurement scales in the evaluation process, Saaty suggested use the maximal Eigen value λ_{max} to evaluate the effectiveness of measurements. The maximal eigenvalue λ_{max} can be determined by Eq. (4) [16].

$$\lambda_{max} = \frac{\sum_{i=1}^{n} cv_i}{n}, \quad i = 1, 2, \dots.., n \tag{4}$$

With the maximal Eigen value λ_{max}, a consistency index (CI) can then be determined by Eq. (5) [13].

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

In Eq. (5), if CI = 0, the evaluation for the pair-wise comparison matrix is implied to be completely consistent. Notably, the closer of the maximal eigenvalue is to n the more consistent the evaluation it. Generally, a consistency ratio (CR) can be used as a guidance to check for consistency [15].

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{6}$$

where RI denotes the average random index with the value obtained by different orders of the pair-wise comparison matrixes (see Eq. (7)).

If the value of CR is below than 0.1, then the evaluation of the importance degrees of customer requirements is considered to be reasonable [17].

$$\mathrm{RI} = 1.98\frac{n-2}{n} \tag{7}$$

Step 5

Determine the relative overall importance degrees of criteria. The relative overall importance of criteria is based on the overall importance degrees of criteria. To deal with the overall importance degrees of criteria, designers must evaluate important weightings from the perspective criteria.

3. Golegohar Iron Mine in Iran

The Golegohar Iron Mine is located about 55 km southwest of Sirjan in the province of Kerman, Iran, between 551150 E and 551240 E longitudes and 29130 N and 29170 N latitudes. This mine, with an altitude of 1750 m above the sea level, is situated at the center of a triangle comprising the cities of Kerman, Shiraz and Bandar Abbas. The Golegohar deposit forms in six separate anomalies at a confinement of about 10 km length and 4 km width. The total ore reserve of the mine is approximately 1135 million tons. This with metamorphic rocks of Paleozoic consists mostly of gneiss, mica schist, amphibolite, quartz schist, marble, dolomite and calcite types of rocks. Anomaly No.3 is the biggest anomaly at this mine. On the basis of exploration work, the total ore reserves of anomaly No.3 are calculated as 616 million tons, with an average grade of 54.3% Fe [18]. Table 1 shows physical and mechanical characteristics of ore deposit of third anomaly [19]. Also, the results of determination of the granular composition in the dump of the Golegohar Iron Mine for various blasting patterns are given in Table 2 [20].

4. Primary crushers

In gyratory crusher a conical shaped element is supported in a flared Shell or frame creating a chamber wide at a top and narrow

Table 1
Technical parameters of ore zone of anomaly No.3 in Golegohar Iron Mine.

Parameter	Quality
General deposit shape	Platy
Ore thickness (m)	40
Ore dip (°)	20 degrees
Grade distribution	Gradational
Depth (m)	150
Uniaxial compressive strength (UCS) (MPa)	128
Overburden pressure (MPa)	15
Joint condition	Filled with talk sleight less than rock substance strength
Rock substance strength (RSS)	87
Rock mass rating (RMR)	615

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