Applied Soft Computing 10 (2010) 1040–1061

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

A new approach to mining method selection based on modifying the Nicholas technique

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ARTICLE INFO

Article history:
Received 16 January 2009
Received in revised form 8 July 2009
Accepted 5 September 2009
Available online 25 September 2009

Keywords:
Mining method selection
AHP
Fuzzy sets theory
Nicholas technique
Optimum profit

ABSTRACT

The main purpose of this paper is to represent a solution to the problem of mining method selection (MMS) in mining projects. To this aim, the well-known MMS technique of Nicholas has been modified so that in addition to eliminate its defects, it would be possible for mining engineers to easily assign their engineering judgments to unsteady and uncertain characteristics of mineral resources. So, in order to resolve the problems of weighting of the Nicholas technique, analytic hierarchy process (AHP) as the most similar multi-criteria decision making (MCDM) tool to Nicholas technique was applied. Due to inability of crisp numbers for assigning of decision maker (DM) judgments to ambiguities of mineral resources, trapezoidal fuzzy numbers also were used for better modeling of those ambiguities. Moreover, a two-step algorithm containing hierarchical technical–operational model (HTOM) and also hierarchical economical model (HEM), inspired by Nicholas technique, was proposed. These models include some new criteria which are added to the Nicholas technique. Therefore using fuzzy AHP (FAHP), mining alternatives are firstly ranked based on HTOM and then, the most profitable of those alternatives is selected by the HEM. As a case study, the north anomaly of Choghart iron mine was used to compare the proposed approach with the Nicholas technique. The results indicated that the proposed approach eliminated the problems of Nicholas technique. Proposed approach also introduces a profitable mining alternative to start the mining operations. It should be applied to avoid further feasibility studies in mining projects.

1. Introduction

Mining methods are those operating methods that are used in order to extract mineral resources from the earth. Considering the complications of the geometrical and geological characteristics of mineral resources, no single mining method can be used for the extraction of all the mineral resources. So, taking the unique characteristics of each mineral resource into account it is necessary to use just the suitable mining method for the extraction of a certain resource, so that the applied method would have the maximum technical–operational congruence with the geometrical and geological conditions of the mineral resource. It is also obligatory for the applied mining method to be profitable in comparison with the other methods [44]. The process of selecting a mining method for the extraction of mineral resources is called MMS. After MMS process is done for a mineral resource and the extraction of that resource is started by the selected method, it is not possible to change the method and replace it with another one. Because such a replacement is usually so costly that the whole project could become uneconomical. MMS is therefore an irreversible stage in mine planning. On the other hand, selecting a mining method for mineral resources is completely dependent on the uncertain geometrical and geological characteristics of the resource. This uncertainty is such that no certain value could be assigned for none of these characteristics. For example a certain slope or volume may not be assigned to mineral resources using crisp numbers. The above-mentioned issues indicate the importance and complication of MMS in mining projects. The sensitivity of MMS in mining projects has led to different solutions introduced by different researchers. Lack of a systematic solution in 70 and 80 decades caused the introduction of some qualitative solutions introduced by Boshkov et al. [9], Morrison [41], Laubscher [33], Hamrin [25], Brady and Brown [10], Hartman [26], Adler and Thompson [1], to find a solution for MMS problem. In these studies, MMS procedure has been looked from qualitative viewpoint. This means that MMS procedure is done by linguistic and qualitative definitions. Furthermore, selection criteria which are used in these

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doi:10.1016/j.asoc.2009.09.002

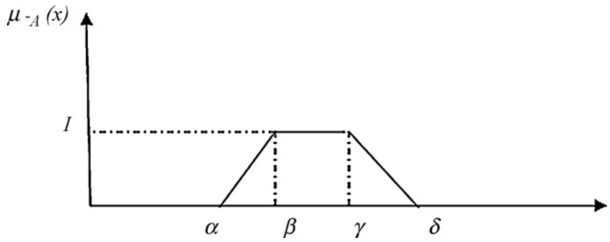

Fig. 1. Trapezoidal fuzzy number $\bar{A} = (\alpha/\beta, \gamma/\delta)$ [11].

studies are insufficient. As another problem of them, these methodologies can be often applied for specific category of mining methods only, such as underground mining methods. They had used some flowchart, tabular definitions and graphs as methodology to select a mining method or a suitable set of them. Generally, based on these classifier methods, some mining methods can be participated into selection process. These methodologies were not adequate to solve the MMS problems.

In 1981, the first numerical approach to MMS was represented by Nicholas. Using some criteria and some mining methods and

Table 1
Fundamental scales to pair-wise comparison in AHP [4,49].

Numerical intensity of importance	Linguistic definitions	Descriptions
1	Equally preferred	Two activities contribute equally to the objective
2	Equally to moderately	Can be used when compromise is needed between 1 and 3
3	Moderately preferred	Experience and judgment strongly favor one activity over another
4	Moderately to strongly	Can be used when compromise is needed between 3 and 5
5	Strongly preferred	Experience and judgment strongly favor one activity over another
6	Strongly to very strongly	Can be used when compromise is needed between 5 and 7
7	Very strongly preferred	An activity is strongly favored, its dominance demonstrated in practice
8	Very strongly to extremely	Can be used when compromise is needed between 7 and 9
9	Extremely preferred	The evidence favoring one activity over another is of tile highest possible order of affirmation

Table 2
Average random consistency (RI) [49].

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3
Weighting procedure of the Nicholas MMS technique: ore geometry attributes [43,44].

Alternatives	Criteria												
	General shape			Ore thickness				Ore plunge			Grade distribution		
	M[a]	T/P[a]	I[a]	N[a]	I[a]	T[a]	VT[a]	F[a]	I[a]	S[a]	U[a]	G[a]	E[a]
Open pit mining	3	2	3	2	3	4	4	3	3	4	3	3	3
Block caving	4	2	0	−49	0	2	4	3	2	4	4	2	0
Sublevel stoping	2	2	1	1	2	4	3	2	1	4	3	3	1
Sublevel caving	3	4	1	−49	0	4	4	1	1	4	4	2	0
Long wall mining	−49	4	−49	4	0	−49	−49	4	0	−49	4	2	0
Room and pillar	0	4	2	4	2	−49	−49	4	1	0	3	3	3
Shrinkage stoping	2	2	1	1	2	4	3	2	1	4	3	2	1
Cut and fill	0	4	2	4	4	0	0	0	3	4	3	3	3
Top slicing	3	3	0	−49	0	3	4	4	1	2	4	2	0
Stull stoping	0	2	4	4	4	1	1	2	3	3	3	3	3

M: massive; T/P: tabular or platy; I: irregular; N: narrow (<10 m); I: intermediate (<10–30 m); T: thick (<30–100 m); VT: very thick (<100 m); F: flat (<20°); I: intermediate (20–55°); S: steep (>55°); U: uniform; G: gradational; E: erratic.
[a] Mining methods.

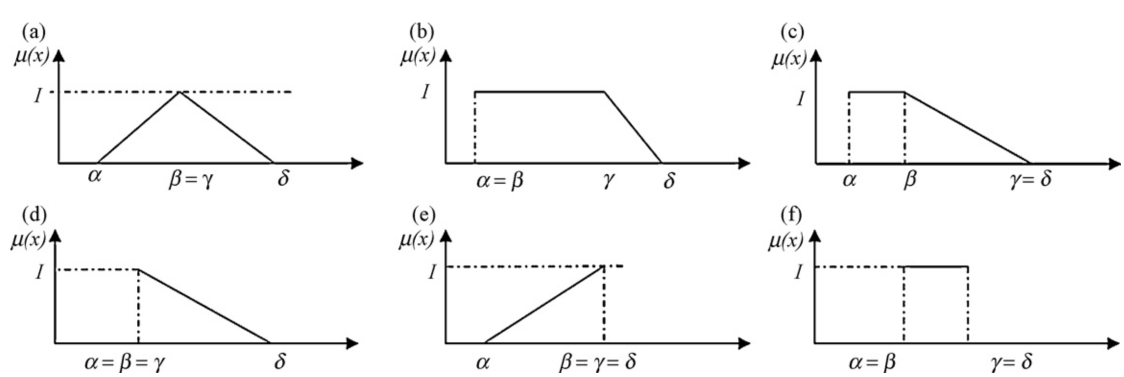

Fig. 2. Fuzzy numbers based on trapezoidal membership of $\bar{A} = (\alpha/\beta, \gamma/\delta)$ which use in fuzzy hierarchy analysis: (a) triangular, (b) more than α to 1, (c) less than δ to 1, (d) between $\alpha/1$ and $\gamma/1$, (e) at least $\alpha/1$, and (f) at most $\delta/1$ [11,12].