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APPLICATION OF PROMETHEE METHOD ON DECISION PROCESS IN MINES

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ABSTRACT: Deciding is eminent in everyday life. In order to simplify and facilitate the decision process, several mathematical methods have been suggested. In the first part of this paper, the basics of multi-criteria techniques, which have been applied in decision processes, are presented. Promethee, Analytical Hierarchical Processes and Electre method are some of the multi-criteria techniques in decision processes. These methods are based on resolving complex problem into hierarchy, where the goal is on top of the hierarchy, while criteria, sub-criteria and alternatives belong to lower level. In the second part of the paper, the example of Promethee method application to pneumatics choices of mine mobile machines is presented. In this part of the paper, the focus is on Dumpers and their pneumatics. In order to objectively analyze the level of competence among pneumatics manufacturers, mathematical method of multi-criteria evaluation, Promethee II, has been used. By using Promethee II method, five pneumatics have been mutually compared according to seven criteria. The results, obtained by multi-criteria evaluation, clearly show that this method of pneumatic selection for Dumper mine machines is successful and applicable.
KEYWORDS: Multi-criteria techniques, Promethee method, tires exploitation

INTRODUCTION

Diging-transportation machines (buldozers, dumpers, grades) perform their working process during movement on traction regime [1]. In open pit mining, during performance of logistic activities there is a high level of risk and danger of increasing costs for mine machines. In open pit mining, after explosions and fuel, tires are the most exploited. Depending on exploitation conditions, their participation in total costs of machine maintenance is up to 25% [2]. For this reason, appropriate choice of tires for mine machines can significantly reduce maintenance costs.

Decision problems of tires types usually come to selection of the best compromising solution. Beside real criteria values by which decision is made, the selection of the best solution also depends on the decision maker, that is, on his individual preferences. In order to simplify the decision process, many mathematical methods have been suggested. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) represents one of the most frequently used methods of multi-criteria decisions. Beside this method, other methods are also available. The Method of Analytical Hierarchical Processes (AHP) and the ELECTRE method took the significant place in mathematical description of complex processes which appear during decisions. All these methods have one basic task, to help the process of alternative evaluation.

In this paper, PROMETHEE II method is used in order to mutually compare five types of tires for mine machines. As a representative, dumper mobile machine has been used, and it is the most used mobile machine in open pit mining. A tires for dumpers is evaluated by experts according to five criteria. As the result of the decision process, we got indexes, that clearly show which pneumatic is the most suitable for exploitation in open pit mining, are obtained. As open pit mining differ, copper mine in Bor is taken for representative location on which dumpers operate.

LITERATURE REVIEW

Decision, as a concept, is widely used, because it is present in everyday life. There are many definitions in decision process: according to H. Koontz and H.Weihrich [3] decision is defined as a choice of most suitable alternative with respect to predefined criteria, while T. Hunjak [4] define decision as collection of activities starting by identification of problems, and finishing with selection of alternative. As in defining the term of deciding, so in the process of decision there are a few different levels [5]: identification and definition of problems, determining collection of alternative solutions (A_i), determining collection of criteria for alternative evaluation (C_j), alternative evaluation and, finally, alternative selection.

PROMETHEE I and PROMETHEE II methods are developed by J. P. Brans and presented for the first time in 1982 at the conference “L’ingénièrie de la decision” organized at the University of Laval

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in Canada [6]. In the same year, several practical examples of application of the methods were presented by G. Davignon [7], and several years later, J.P. Brans and B. Mareschal developed PROMETHEE III and PROMETHEE IV methods [8, 9]. The same authors also suggested visual, interactive modulation GAIA, which represents a graphic interpretation of PROMETHEE method, and in 1992 and 1995, they suggested two more modifications – PROMETHEE V and PROMETHEE VI [10, 11]. Many successful implementations of PROMETHEE method into various fields are evident, and as such, these methods found their place in banking, investments, medicine, chemistry, tourism, etc [12].

PROMETHEE METHOD

PROMETHEE method is based on mutual comparison of each alternative pair with respect to each of selected criteria. In order to perform alternative ranking by PROMETHEE method, it is necessary to define preference function P (a, b) for alternatives a and b after defining criteria. Alternatives a and b are evaluated according to criteria functions. It is considered that the alternative a is better than alternative b according to criterion f, if f (a) > f (b). Decision maker has possibility to assign the preference to one of the alternatives on the basis of such comparison. The preference can take values on the scale from 0 to 1, and relation combinations are possible to present using following relations:

P (a, b) = 0 no preferences, indifference,
P (a, b) ≈ 0 weak preference k (a) > k (b),
P (a, b) ≈ 1 strong preference k (a) >> k (b),
P (a, b)=1 strict preference k (a) >>> k (b).

Relations have following limitations:

$$0 < P(a,b) > 1, \tag{1}$$

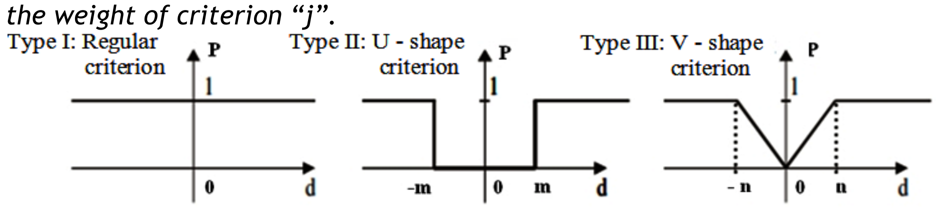
$$P(a,b) \neq P(b,a). \tag{2}$$

Higher preference is defined by higher value from the given interval. This means that, for each criterion, the decision maker considers certain preference function [13]. In figure 1, six generalized criteria are given and six preference functions P (d). All six generalized criteria are possible to illustrate via linear functions, that is, they are obtained by choosing the highest four points inside criteria space of the given criterion. In figure 1, beside criteria functions, parameters for chosen points within criteria space, which is illustrated in x-axis, are given, and the level of preference is given in y-axis (P). In the four-level criterion, instead of value P(d) = ½, it is possible to give any value 0 < P(d) < 1.

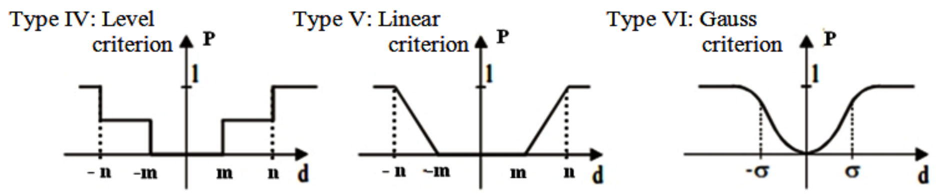
After defining the type of general criterion, it is necessary to determine the value of function preference of action a in relation to action b for each criterion, and calculate the index of preferences (IP) of action a in relation to action b. Each pair of actions is in set A. The index preference is calculated in the following way:

$$IP(a,b) = \sum_{j}^{n} W_j P_j(a,b), \quad b\sum W_j = 1 \tag{3}$$

where W_j is the weight of criterion "j".



$$P(d) = \begin{cases} 0, & d \le 0 \\ 1, & d > 0 \end{cases} \qquad P(d) = \begin{cases} 0, & d \le m \\ 1, & d > m \end{cases} \qquad P(d) = \begin{cases} 0, & d < 0 \\ d/n, & 0 \le d \le n \\ 1, & d > n \end{cases}$$



$$P(d) = \begin{cases} 0, & d \le 0 \\ 1/2, & m < d < n \\ 1, & d \ge n \end{cases} \qquad P(d) = \begin{cases} 0, & d \le m \\ \dfrac{d-m}{n-m}, & m < d \le n \\ 1, & d > n \end{cases} \qquad P(d) = 1 - e^{-\frac{d^2}{2Q^2}}$$

Figure 1. Types of preference functions P (d) with parameters that illustrate them

If all criteria have the same weight, that is if $W_j = 1/n$, so the index preference is:

$$IP(a,b) = (1/n)\cdot\sum_{j}^{n} P_j(a,b) \tag{4}$$

and which is determined by the following relation:

$$0 \leq P_j\,(a,b) \leq 1 \tag{5}$$

After determining index preference IP (a, b), it is finally possible to calculate alternative flaw index T (a), the value of which represents the significance of the alternative. According to this index, the final decision about adequacy of one alternative from the set of alternatives is made. It is determined as:

$$T(a) = \frac{\sum_{x\in A} IP(a,x)}{i-1} \tag{6}$$

The selection of criteria to be used in the decision process needs to be done carefully so that the majority of chosen criteria define the problem at hand adequately and in accordance with decision maker's given requests [14]. In this way, the influence of experience and subjective evaluation of decision maker during selection of generalized criteria is maximally reduced.

APPLICATION OF PROMETHEE METHOD FOR SELECTION OF PNEUMATICS

Application of Promethee method in this paper is used for selection of pneumatics for mobile dumper machine which operate on open pit mine. The dimension of dumper pneumatic is 27 R49 (width, radius) and decision maker chooses one of five offered pneumatics. As the alternatives, the following five types of tires are considered (A_i = 5): Goodyear with tires types RT-4A (A_1) and RL-4J (A_2), Bridgestone with tires types VMTP (A_3) and VRDP (A_4), and Double Coin with tires type REM-9S (A_5). During evaluation of alternative (A_i), seven C_j=7 criteria have been used (figure 2). The criteria are marked with indexes C_j and they include: price (C_1), performance (C_2), maximum speed (C_3), weight (C_4), strength (C_5), comfort (C_6) and index of tires warming (C_7).

After defining alternatives and criteria, it is necessary to evaluate weight coefficients W_j, according to which given alternatives are evaluated.

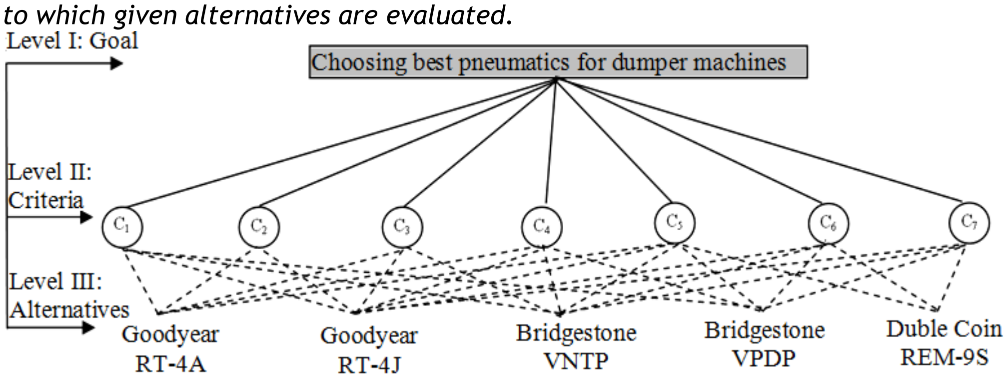


Figure 2. Basic parameters in PROMETHEE II method (alternatives A_i and criteria C_j)

Certain criteria, such as comfort and heating of pneumatics, are evaluated by experts who operate on pneumatics. Such an approach reduces the mistake of subjective evaluation of the author considerably. The results of ranking and criteria evaluation are illustrated in table 2 by experts. The experts used scale (table 1) for qualifying qualitative values of criteria C_j [15], similar solutions have been also offered by another multi-criteria methods [16].

Table 1. Linear quantifications of qualitative attributes

1	2	3	4	5
Very low	Low	Medium	Strong	Very strong

Beside alternative and criteria evaluation, weight coefficients of criteria are also presented in the table 2.

Table 2. Evaluation of criteria C_j for each alternative-pneumatics A_i on the level of importance

Alternative	Price	Performance (tkph)	Consistence (lbs)	Comfort	Pneumatic heating	Weight (kg)	Maximum speed (km/h)
	min	max	max	max	min	min	max
RT-4A	5	394	60000	5	5	1389	50
RL-4J	5	440	60000	5	4	1337	50
VMTP	3	544	59900	3	3	1310	50
VRDP	3	513	59900	3	3	1400	50
REM-9S	1	425	59850	1	1	1412	50
Weight Wi	0.3	0.2	0.2	0.1	0.1	0.05	0.05

Experts also assigned following weights to criteria: The sum of all weight criteria equals 1. The value of assigned weights show that the decision maker, during decision process, will equally evaluate *criteria of comfort and pneumatic heating, as well as weight criteria and maximum speed. The first two criteria are at the same time significant for decision maker during pneumatic selection. It is easy to note that maximum speed is the same for all types of pneumatics, so this criterion does not influence final decision during pneumatic selection. Other criteria values are taken from producer's catalogue.*

Beside weight factors W_j, a decision maker has to be able to assign to each C_j criterion a corresponding preference function P(d).

Beside the preference function, it is necessary to determine which function is minimized and which is maximized.

In this work in table 2, criteria that belong to financial category and criteria which have negative influence on pneumatic performance are minimized, while criteria which influence on improving of pneumatics are maximized.

By final implementation of PROMETHEE II method in the process of solving problems of multi-criteria deciding for evaluating indexes of preferences IP (a,b) (3), the results of final index of alternative flaw T(a) (6) are obtained, and their values are illustrated in Table 3.

In table 3, it is clearly obvious that both types of Bridgestone pneumatics are most suitable for operations on surface diggings of mines. It means that VMTP pneumatic, according to previously mentioned criteria, offers the most suitable conditions of exploitation.

Table 3. Final pneumatics ranking on the basis of T(a) index

Alternative	Bridgestone VMTP	Bridgestone VRDP	Goodyear RL-4J	Goodyear RT-4A	Double Coin REM-9S
Rang	1	2	3	4	5
T(a)	0.225	0.150	0.001	-0.125	-0.250

RESULTS ANALYSIS

In order to analyze the results, special software for data processing, D-Sight [17], has been used. The platform, on which D-Sight software has been developing, is closely connected to PROMETHEE method. D-Sight program facilitates development of the model according to the PROMETHEE method through the following steps: setting alternatives, setting criteria, setting weight coefficients for criteria separately, setting alternatives' weights and their normalization, determining function of criteria and their maximization/minimization, and reading results. Similar solutions have been also offered by Tomic [18].

Graphic illustration of result processing is obtained by using Global Visual Analysis tools (GVA), and it's illustrated in figure 3. The point P denotes an approximate value of all criteria weights and visually illustrates the optimal point, which the alternatives tend to achieve. Reading the results obtained by PROMETHEE method of multi-criteria decisions supported by program D-Sight, it is graphically confirmed that Bridgston VMTP has the strongest T(a) index.

By analyzing results, criteria which contributed to Bridgston VMTP's strong index is reasonable price and excellent performance and low weight of pneumatics, while on Double Coin REM-9S, criteria which influenced negative T(a) index the most are: weaker consistence, less comfort and greater heating of pneumatics.

In figure 3, given solutions are visually illustrated. Here, the alternatives are presented as points, while criteria are presented as axis. If alternatives spread away towards one axis of criteria, it means that the given alternative is good for the given criterion. For example, Bridgestone VMTP is by performance a way ahead of other alternatives, so this pneumatic is deep into the axis of this criterion. It is similar with VRDP pneumatic which has the highest price competence, so it is also deep into the axis of the criterion. On the other side, Goodyear RT-4A and RL-4J is the most expensive, and that is why they are opposite the axis of this criterion, but by comfort very close to axis criterion of comfort. If these two axis are in the same direction, it means that those two criteria are in correlation with each other.

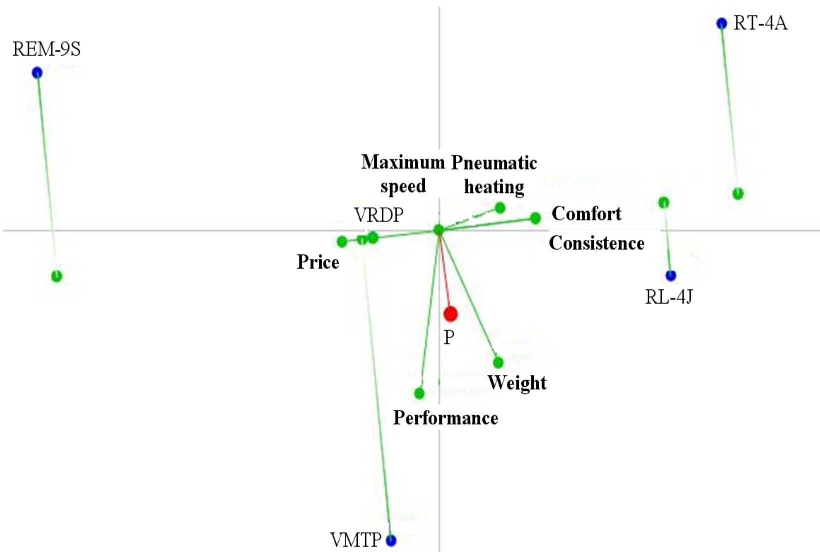


Figure 3. Obtained alternative solutions by using D-Sight software

On the other side, if axis go into the opposite direction it means that criteria are positive. For example, in figure 3, it is clearly obvious that the axis of price criterion is opposite axis of consistence and comfort criteria. It means, the higher the price, the greater consistence and comfort of pneumatics. And during pneumatic selection, we try to minimize the price and maximize the other two criteria, so that is why these criteria are in "conflict" and they are situated opposite sides. Red axis stands for the axis of compromise for all criteria and all alternatives strive to get closer to this axis, or point P. The closer the alternative to axis, the more desirable as final solution.

Figure 4. Comparison of type pneumatics of VMTP and REM-9S

By applying D-Sight software, the best alternatives Bridgestone VMTP and Double Coin REM-9S are compared. In figure 4, advantages and disadvantages of Bridgestone VMTP pneumatic in relation to Double Coin REM-9S are illustrated. It is clearly obvious that Bridgestone VMTP for price criterion has the value of 0.25 while Double Coin REM-9S has 1 value for the some criteria as the best ranged. It means that Double Coin REM-9S by this criterion is much more competent than Bridgestone VMTP. This way, weight coefficients of other criteria are compared. The last criterion, as it is obvious in figure 4, does not have any influence on decision maker.

CONCLUSIONS

Primary aim of this research is to obtain T(a) indexes by using multi-criteria analysis which will help to choose pneumatics for dumper machines. In this work, PROMETHEE method is used, as well as a mathematical tool in order to obtain T(a) indexes. PROMETHEE method is ranked as one of the most famous and most frequently used methods of multi-criteria decisions. Theoretic basis of this method has been presented, and its application has been demonstrated by finding T(a) indexes for dumper tires.

By applying Promethee method T(a) index is obtained for five pneumatics according to 7 criteria. According to results, Bridgestone VMTP pneumatic proved to be the best solution, while the second and the third ranged are Bridgestone VRDP, Goodyear RL-4J, Goodyear RT-4A and Double Coin REM-9S. According to T(a) index, it is possible to determine the level of pneumatic competence on surface diggings with mine machine dumper in relation to other alternatives. By using D-Sight software, analytic solutions are qualitatively analyzed and verified.

Beside its quality, the success of PROMETHEE method implementation in the process of deciding greatly depends on possibilities and experience of decision maker, because decision maker has to be able to prove the significance of each criterion and define it on an interval scale.

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