Acta logistica - International Scientific Journal about Logistics
Volume: 5 2018 Issue: 2 Pages: 39-43 ISSN 1339-5629

doi:10.22306/al.v5i2.89 *Received: 28 Apr. 2018*
Accepted: 16 May 2018

DETERMINATION OF IMPORTANCE OF ORE RAW MATERIALS EVALUATION CRITERIA

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Keywords: costs, production, ore, price
Abstract: Industrial enterprises are now obliged to solve complicated and comprehensive problems. As a rule, they have a multi-criteria character, whereas separate criteria have fundamentally different properties. Logistics mathematics-based tools enabling the evaluation of these complicated problems are being more and more applied at present. A common problem can be the evaluation of a series of supplier's offers for commodities, which are typical by a wide spectrum of properties. It could be, for example, input production raw materials. A possibility of the use of mathematic tools in evaluating the quality of the ore raw materials was analysed within the performed investigation. The paper deals with an analysis of the results in determining a relevant importance of separate criteria.

1 Introduction

The tasks of multi-criteria decision-making in our understanding is such decision-making tasks, in which the consequences of particular decisions are evaluated by several criteria. The settling of a task of multi-criteria decision-making is, then, a procedure, by application of which we are able to find out an optimal state of the system, and that is with regards to more than one considered criterion [1].

Decision-making problems and processes can be divided by many aspects. At basic classification of decision-making problems and processes, we can use a division to sufficiently and insufficiently structured decision-making problems, when the basic classification aspect is the division of the problems by aspect of their complexity and ability of algorithmization; decision-making processes under conditions of certainty, risk or uncertainty, whereas the classification aspect is information on the states and consequences of the versions with regard to separate evaluation criteria; dependent and independent decision-making processes [1,2].

As a rule, the sufficiently structured decision-making problems are repeatedly solved on the operative level of management and there are routine procedures of the solution for them. What is typical for these problems is that variables, which occur in them, can be quantified and, as a rule, have the only quantitative criterion of evaluation [3]. The insufficiently structured decision-making problems are typical by such characteristics as a solution of higher levels of management, their novelty and often non-repeatability, a necessity of application of a creative approach, the usage of knowledge, experience and intuition, existence of a higher number of criteria for the evaluation of the solution versions or complicated interpretation of information used for decision-making [4,5].

Another aspect is range and character of criteria, which characterize this decision-making problem. We often meet with problems in the sphere of logistics, which are typical by a wide spectrum of criteria, which additionally have absolutely different properties [6]. We have to synthesize fully different properties for the evaluation. A possibility of the use of tools of multi-criteria decision-making in the evaluation of ore raw materials was analysed within the performed investigation. The fundamental aspect is the determination of importance of the evaluated criteria in a form of weights. Accordingly, their value determines the result of evaluation. A method of paired comparison was used within the investigation. This tool enables simplification of the decision-making process because the evaluation is based on a preference of one of two versions.

2 Importance of the evaluation criteria

While using most of methods of multi-criteria decision-making, it is firstly required to determine a weight of separate criteria of evaluation. The preferences of particular criteria are expressed by criteria weights, respectively their values, and information on relative importance of separate criteria is thus specified [7]. This importance can be expressed by a vector of the weights of the criteria. The more significant the criterion is, the higher weight it has, and conversely, less significant criteria have lower weights. That's why the weights of the criteria are occasionally called as importance factors [8]. In practice, it is very difficult to obtain precise values of the weights from a user; that's why there was developed a series of methods, by means of which estimations of the weights are designed on the basis of simple subjective information from the user. The methods of the weights determination can be divided to two classes. As far as the determination of the weights is independent of the knowledge of impacts of the versions, methods of direct determination of the weights can be used, such as a point scale, allocation of 100 points (also referred to as the point method) and a method of weights determination by comparison of the criteria by means of their preferential order. Methods based on the paired comparison includes a paired comparison method, which uses so called the Fuller's triangle, and Saaty's method. In case that the results of the methods have to be known, a compensation method is used to determine the weights of criteria. The method of gradual weights allocation, which can be combined with other methods, is used in case when a great number of criteria is available.

3 Criteria of evaluation of an ore raw material

The evaluation of quality of the ore batch can be realized from different points of view. In principle, three basic possibilities can be identified:

- evaluation of the behavior of ore while its lowering through the well of the high furnace,
- single-purpose proving tests serving for the determination of a selected metallurgical indicator,
- complex approaches for the evaluation of ores.

The problem of evaluation of the ore raw materials is complicated with regard to the wide spectrum of the relevant criteria, which evaluate fully different characteristics and have different dimensional indicators. It very complicates comparing particular types of ore. One of the opportunities is the use of the multi-criteria mathematic methods for the evaluation of ores. Firstly, however, it is necessary to determine the importance (the weight) of particular criteria. The following seven criteria were selected for the evaluation of the ore raw materials:

1. Ore price (dollar / ton)
2. Iron content (%)
3. Ore strength after testing in a drum, according to ISO (%)
4. Homogeneity of lumpiness (Vx, %)
5. Quantity P (%)
6. Reducibility (%)
7. Humidity (%)

Criterion 1 (hereunder referred as K1) - Price

The ore price in the present economic conditions belong to the key parameters. Strong competition makes metallurgical enterprises continually search for potential savings. Therefore, the ore ingredient as a basic input raw material for the high-furnace process is a dominant component from the costs point of view. Lately, the price of ore strongly fluctuates, which naturally influences the cost level of the entire process. Metallurgical enterprises often struggle to look for cheaper sources of ore raw materials, which, however, can mean a significantly worse quality, which will be expressed itself by worsening the technological parameters of the high-furnace process. It is necessary to realize in this regard that the energy intensity of the production of raw iron directly depends on the properties of the used ore, and - thus - the ore type directly determines the production costs.

K2 - Iron content

The content of iron belongs to the basic characteristics of the demanded raw materials influencing the effectiveness of the entire process. The content of iron in the ore raw materials shouldn't be long-term under the limit of 50 %. Raw materials containing iron in an amount higher than 65 % may be considered as excellent. The content of iron is naturally given by a type of ore (oxide, carbonate, silicate).

K3 - Ore strength after testing in a drum

The ore strength belongs to the physical properties influencing the high-furnace process. The strength is expressed by a share of class under 0.5 mm and above 6.3 mm; and after testing in an ISO drum should be generally: the share under 0.5 % should be lower than 5 % for ores and pellets, the share of class under 6.3 mm should be higher than 75 % for ores and higher than 90 % for pellets.

K4 - Homogeneity of lumpiness

Homogeneity of lumpiness, which was evaluated on the basis of a coefficient of variation, was selected as the fourth evaluating criterion. The coefficient evaluates variability in a form of percentage, and its growing value means a higher rate of fragmentariness. The ore lumpiness belongs to the frequently used international classification scales of ores, which set up raw materials to several groups.

K5 - Phosphorus content

The content of negative elements in the high-furnace process is very crucial. The negative elements can be a cause of violation of the course of the high-furnace process and invoke a quite a few of typical causes. The most frequent of them are sudden changes of the speed of gas flowing, a swift decrease of the batch, an excessive warming-up of the well of the furnace. Also, viscosity of slag or raw iron is often changed, which means problems with their withdrawal from a high furnace. Other effects can be related to the influence of the service life of the lining and its integrity. A series of these causes can be caused by pollutants, such as alkaline carbonates, zinc, phosphorus, lead and other negative elements.

K6 - Reducibility

The sixth evaluating criteria is reducibility, which belongs to the important properties of the metallic batch. The reduction of iron oxide belongs to the elementary processes ongoing in a high furnace. The reducing processes proceed practically in the entire high furnace with the exception of relatively small oxidizing spaces in

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the well. Reducibility of ore fundamentally influences the effectiveness of the entire high-furnace process.

K7 - Humidity

The last evaluating criterion is humidity, i.e. a quantity of H20 concentrated in the ore raw material. The content of free or bound water can also essentially influence the costs of both agglomerative and entire high-furnace processes.

4 The results of the performed investigation

For the estimation of the weights, the method of paired comparison only uses information about which of the two compared criteria is more important. The resolver gradually compares each two criteria among each other. The comparison can be carried out in the Fuller's triangle. Firstly, we firmly number the criteria by sequential numbers: *1,2,…k*. Afterwards, a triangle scheme is presented to the resolver. Its double-rows contain pairs of the sequential numbers configured so that each pair is unique here. The resolver is required to mark such a criterion for each pair which he/she considers to be the most important.

Considering the above, the base for the paired comparison method is the comparison of all criteria in the pairs with the aim to determine how many times each criterion is considered to be the most significant in comparison with all other criteria. The most significant criterion is thus a criterion with the biggest number of preferences. The preferences are considered as non-normed weights, which have to be consequently recalculated to the normed ones. Sometime, however, a certain criterion obtains a zero preference, which should mean that is has zero importance. But, based on the principle of the selection of the criterion for decision-making, it is unequivocally clear that each selected criterion has a certain importance. In this case, an additional consideration of the obtained preferences is being performed. The procedure of the determination of the weights with help of the paired comparison method can be divided into the following steps:

1. Determination of the number of preferences for each criterion (P_{pi}) (how many times each criterion is more significant than all others)
2. Calculation of the weights of particular criteria (v_i) according to the formula (1)

$$v_i = \frac{n+1-p_i}{n(n+1)/2} \tag{1}$$

where

n – total number of criteria

p_i – order of each of the criteria depending on the number of the obtained preferences,

1. Evaluation of the determined weights
2. Determination of the order of particular criteria

The paired comparison method was applied within the performed investigation for the evaluation of the criteria importance for the evaluation of iron ore. The respondents in the company, dealing with the metallurgical production, carried out evaluation of the followed criteria with help of the binomial comparison system. The record of evaluation is part of Table 1. The left part of the table contains a record of the performed decisions. The votes assigned to each criterion (*Ppi*) were also summarized. Based on the assigned votes, an order of particular criteria was compiled. A criterion which obtained the highest number of votes is put on the first place. The last step was the calculation of the normed weights with help of the formula (1). An example of weights calculation:

$$V_{i1} = \frac{7+1-3}{7(7+1)/2} = \underline{\underline{0,1785}}$$

$$V_{i2} = \frac{7+1-2}{7(7+1)/2} = \underline{\underline{0,2142}}$$

$$V_{i3} = \frac{7+1-1}{7(7+1)/2} = \underline{\underline{0,2500}}$$

$$V_{i4} = \frac{7+1-7}{7(7+1)/2} = \underline{\underline{0,0357}}$$

$$V_{i5} = \frac{7+1-6}{7(7+1)/2} = \underline{\underline{0,0714}}$$

$$V_{i6} = \frac{7+1-5}{7(7+1)/2} = \underline{\underline{0,1071}}$$

$$V_{i7} = \frac{7+1-4}{7(7+1)/2} = \underline{\underline{0,1428}}$$

All steps of the paired comparison method are shown in Table 1. The calculated weights (*Vi*) are an evaluation criterion, according to which all criteria are compared. The higher the criterion weight is, the higher importance it has.

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Table 1 Record of the paired comparison method

K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_i	P_{pi}	P_i	V_i
	2	3	1	5	1	1	K_1	3	3.	0,1785
		3	2	2	2	7	K_2	4	2.	0,2142
			3	3	3	3	K_3	6	1.	0,2500
				5	6	4	K_4	1	7.	0,0357
					6	7	K_5	2	6.	0,0714
						7	K_6	2	5.	0,1071
							K_7	3	4.	0,1428

The final order of the followed criteria for the evaluation of ores is shown in Table 2, and in a form of a diagram in Figure 1. The criterion No. 3 is on the first place; and - on the contrary - the worst evaluation is for the criterion No. 4, which was evaluated by the lowest weight.

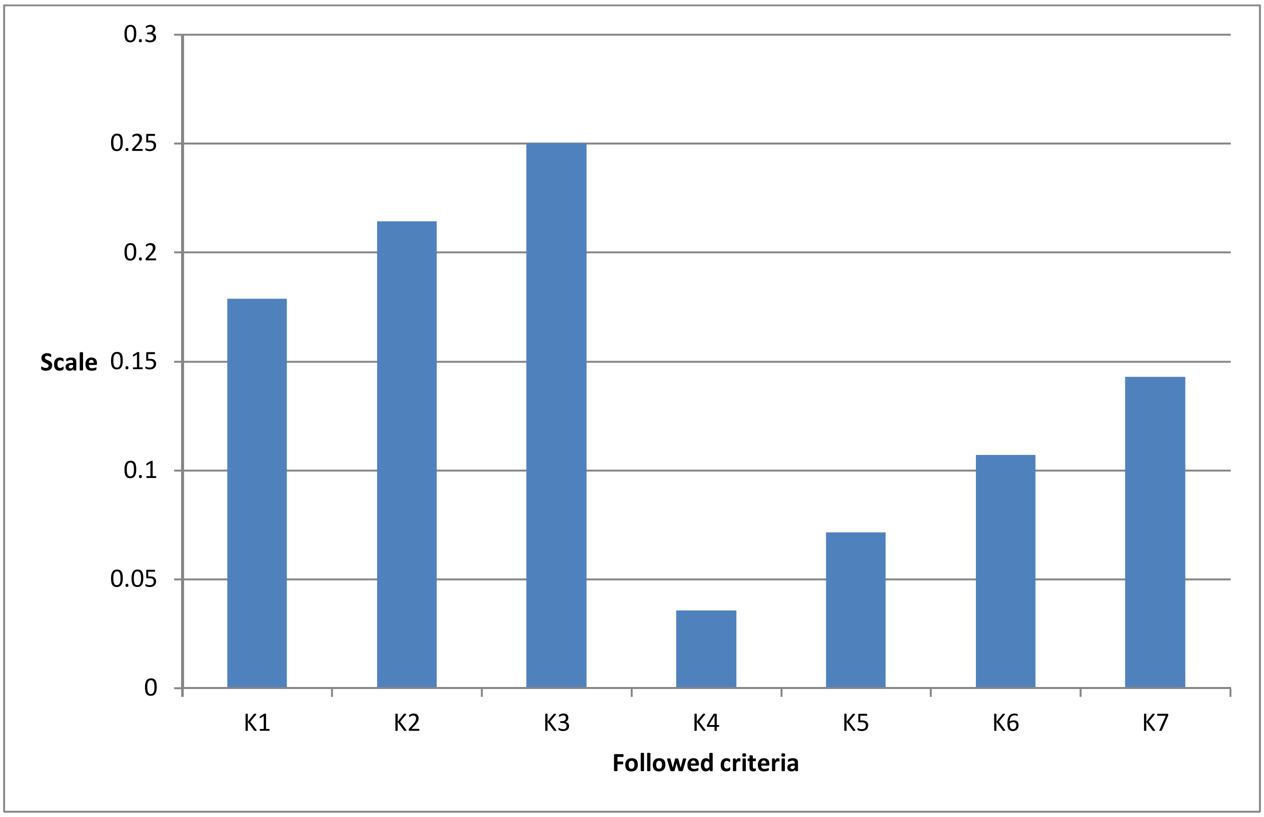

Figure 1 Values of the weights determined by the paired comparison method

Table 2 Total evaluation of the paired comparison method

Criterion	K1	K2	K3	K4	K5	K6	K7	∑
Weight	0.1785	0.2142	0.2500	0.0357	0.0714	0.1070	0.1428	1

The weights determined for the specified criteria can be used in evaluating particular ore raw materials. The weights finally represent an importance of separate criteria.

5 Conclusion

The tools on the basis of the paired comparison offer an interesting occasion how to easily determine the importance of particular criteria. Their usability is mainly suitable where a wide spectrum of criteria must be evaluated. In this case, it will be always complicated for a respondent to divide weights between a bigger numbers of criteria in case of the paired comparison, on the opposite, the respondent has to make a decision just between two alternatives. This aspect fundamentally simplifies the entire decision-making process. The paired comparison method was applied within the realized investigation of the evaluation of the ore raw materials. Its simplicity, universality and algorithmic unpretentiousness enable the use in a wide spectrum of industrial spheres. Its usage can be high-effective in the sphere of the industrial logistics, where there are problems having a similar multi-criteria character.

Acknowledgements

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic No. SP2018/109.

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Review process

Single-blind peer review process.