UTILIZATION OF LOGISTICS TOOLS IN THE CONTROL OF METALLURGICAL PROCESSES

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Abstract

Metallurgical production is based on the use of a wider range of technological processes, but also on a large number of input raw materials. The current highly competitive environment also brings considerable demands on the optimization of all partial processes and operations. Reducing total costs, increasing the efficiency of individual activities, reducing resource consumption are just some of aspects that must be solved by the current metallurgical enterprises. The quality of input raw materials in the blast-furnace process has a significant influence on the technological and economic parameters. The assessment of input raw materials is complicated due to the variety of parameters monitored. These may be the characteristics of chemical, physical, technological, but also operational-economic characteristics. An interesting alternative is the use of logistics tools based on multi-criteria decision making, which will allow to quantify the significance of all relevant criteria. In the framework of the research carried out, a method of weighing the raw materials in the conditions of a selected iron producer in the Czech Republic was applied. The aim of the article is to present the results of the research and possible areas of further use in the environment of metallurgical primary production.

Keywords: Logistics, costs, ore, quality, price

1. INTRODUCTION

Strong competition, the ever-rising cost of raw materials and energies forces steel companies to continually increase the efficiency of their production processes. It is more and more necessary to exactly monitor, evaluate, measure and regulate all processes. The main objectives of blast furnace operators include the maximum production of raw iron with the required chemical composition at minimum cost. This can only be assured by the quality of the raw material base and the trouble-free operation of the blast furnace [1].

A number of metallurgical processes can be characterized by a wide range of parameters. In their evaluation, it is then possible to use logistics tools that are used in other areas [2]. One example of metallurgical production, which is based on monitoring a number of parameters, is the evaluation of ore raw materials. Current methods of evaluation of the quality of ore raw materials can be divided into two groups of methods from a general point of view. The first attempts to simulate the conditions that the ore is exposed to when dropping through the blast furnace shaft. On the basis of these information, we can make further technology control of the process. Another approach consists of single-purpose tests designed to determine the selected metallurgical quality indicator. Both of these approaches enable you to obtain a range of key information on the quality of ore and the blast furnace process. However, using these methods, it is not possible to obtain comprehensive information that offers a global view of the total value of the ore raw material [3]. To evaluate raw materials, it is appropriate to find a system that will transform a wider range of parameters into one selected indicator. This can also be beneficial in the operational comparison of ore raw materials that ironmongers have to implement within the purchasing process [4,10]. If we only evaluate the isolated parameters of the ore, the long-term decision to purchase them may be ineffective [5,6].

The aim of the article is to present the results of the research carried out in the area of application of selected multi-criteria decision making tools in the middle metallurgical production. The evaluation is based on the results of contractual research in the implementation of logistics tools in metallurgical processes.

2. PROBLEM FORMULATION

The quality of ore raw materials significantly influences the technological aspects of the blast furnace process. When evaluating ore raw materials, we can observe a large number of completely different criteria. Categorically, important parameters can be classified into three groups based on properties: chemical, physical, technological [7]. We rank among elementary chemical parameters of ore raw materials the content of iron, the amount of harmful substances (sulfur, phosphorus, zinc, alkali), but also alkalinity. Of the important physical properties, we can mention mainly quantity, humidity, porosity or magnetic properties. Technological properties include strength, reducibility, and thermoplastic properties [8]. We can therefore derive dozens of parameters from the evaluation of ore raw materials, which makes it very difficult to compare them in terms of overall quality.

In the framework of the research carried out, a weight-grading method for quality evaluation of ore raw materials was experimentally used. The weighted-grading method is one of the tools of multi-criteria decision making and is very often used in logistics processes.

The method is characterized by an effort to find the total value of individual variants (in our case, ore minerals). It is based on the weighted average of the partial evaluations of variants according to the criteria. The optimal variant is the variant with the largest total weight. The principle of the method is that, for all criteria, their ranking is determined in terms of the degree of fulfillment of the individual criteria. If we evaluate the price of the ores traced, we will compile their ranking according to a specific price [8]. We will also sort the other monitored criteria in the same way [8]. This order then enters an overall rating that takes into account the weighting of the individual criteria [9]. The procedure for determining a preferential arrangement of variants by the weight-grading method can be summarized as follows:

- determining the weights for each criterion (v_i),
- determining the order of each variant in terms of each of the criteria (p_{ij}),
- calculation of the partial evaluation of each variant according to each criterion (h_{ij}) according to the relation (1):

$$h_{ij} = m + 1 - p_{ij} \tag{1}$$

where: m - is the total number of variants

- calculation of the total value of individual variants (H_j) according to the relation (2):

$$H_j = \sum_{i=1}^{n} v_j h_{ij} \tag{2}$$

where: n - is the total number of criteria

- determining the order of variants - the best option is the one that has the highest total value (Hj).

The overall evaluation of the order of the monitored variants (ores) is basically aggregated into one pointer whose value is used for descending ordering of variants. For comparison, three ores were selected. The values of the monitored criteria were processed on the basis of the input data provided by the suppliers. For all the monitored criteria their significance (weight) was established.

3. EXPERIMENTAL WORK

Within the research, a comparison of ore raw materials from Australia, Brazil and Ukraine was carried out. The evaluation was carried out as part of realized project for a selected iron producer in the Czech Republic. The criteria were defined for all ore raw materials for their evaluation. The primary point of view was the possibility of using the aforementioned assessment procedure for the operative comparison of the demanded ores. Five key criteria were selected for evaluation. **Table 1** shows these criteria along with information about their specific values.

Table 1 Monitored species of ore

Criteria		Raw materials (state - locality)		
No.	**Name**	**Australia Marillana**	**Brazil Carajás**	**Ukraine Krivoy Rog**
K1	Fe content (%)	62	67	58
K2	P content (%)	0.075	0.033	0.030
K3	S content (%)	0.022	0.006	0.015
K4	Reducibility (%)	63	64	64
K5	Price ($/t)	76	72	64

For further evaluation using a weighted order method, it is necessary to sort the values of the observed criteria for individual ore raw materials. On the basis of the input data presented in **Table 1**, the order of individual ore raw materials was compiled for all criteria. In the case of iron content, individual ores were ranked in descending order according to the values given in **Table 1** and the order was entered in **Table 2**. On first place was the ore from Brazil (67 %), the second was the Australian ore (62 %) and the third was the Ukraine ore (58 %). All other criteria were evaluated in the same way. The exact order of all the criteria for the observed species of ores is given in **Table 2**.

Table 2 Sequence of criteria for each species of ore

Criteria		Ore raw materials		
No.	**Name**	**Australia Marillana**	**Brazil Carajás**	**Ukraine Krivoy Rog**
K1	Fe content	2.	1.	3.
K2	P content	3.	2.	1.
K3	S content	3.	1.	2.
K4	Reducibility	2.	1.	1.
K5	Price	3.	2.	1.

The implementation of the procedure and the results of the weighted order method for the observed species of ore is included in **Table 3**. For each criterion in the column *V*1 is given the weighting of the criterion (importance). This was determined using the pairwise comparison method, where a binomial comparison of the meaning of each criterion was made. The columns p_{i1}-p_{i3} show the order of the individual criteria for a particular type of iron ore. The h_{i1} - h_{i3} column shows the recalculated order for each ore according to formula (1). The $V_i x h_i$ column (1-3) shows the multiplication of the weight and the recalculated order. The sum of these weights for each monitored ore raw material is then an evaluation parameter. Depending on the result the order of the monitored ore raw materials (line - order of the species of ore) is compiled.

Table 3 Evaluation of the quality of the monitored ores

Criteria		Scale	Ore raw materials								
No.	Name	(0-1)	Australia Marillana			Brazil Carajás			Ukraine Krivoy Rog		
		v_i	P_{i1}	h_{i1}	$V_i x h_{i1}$	P_{i2}	h_{i2}	$V_i x h_{i2}$	P_{i3}	h_{i3}	$V_i x h_{i3}$
K1	Fe content	0.30	2.	2	0.60	1.	3	0.90	3.	1	0.30
K2	P content	0.10	3.	1	0.10	2.	2	0.20	1.	3	0.30
K3	S content	0.15	3.	1	0.15	1.	3	0.45	2.	2	0.30
K4	Reducibility	0.25	2.	2	0.50	1.	3	0.75	1.	3	0.75
K5	Price	0.20	3.	1	0.20	2.	2	0.40	1.	3	0.60
	∑				1.55			2.70			2.25
	Order of species of ores				3.			1.			2.

The methodology for the evaluation of the results is based on the principle of descending order of the total value of the monitored ore raw materials. Under this procedure, the monitored ores were ranked in the following order: 1. Brazil, 2. Ukraine, 3. Australia.

4. RESULTS AND DISCUSSION

For evaluation were selected ores from Australia, Ukraine and Brazil. The ranking found according to these criteria is included in **Table 3**. Brazil's ore was placed first. This ore contained the highest amount of iron, and at the same time was first in the case of the reduction criterion. In terms of price, however, it was cheaper than Australia's ore. The second place was the ore from Ukraine. The lowest price was significantly contributed to this. This is also supported by the weight of this criterion. Third place was the ore from Australia. Its main disadvantage is higher content of pollutants, but also the highest price. Its final evaluation did not affect the high iron content, which was significantly higher than the ore from Ukraine. From a general point of view, it is interesting that as the best was not designated ore with only the lowest price. If we evaluated everything only by cost criteria or through one of isolated parameters, the solution would not need to be effective in the long run. The determined order of ore materials is determined by the values of the mentioned criteria but also by their weight. Changing the meaning of the criteria may also make a possible change in the final order.

5. CONCLUSIONS

The weighted order method enables to quantify the wide spectrum of properties of the surveyed ores. A big advantage lies also in its algorithmic modesty. At the same time, it allows to synthesize the values of criteria that are fundamentally different. The evaluation is based on a wider range of criteria, not just on the comparison of isolated parameters. Using the applied method in assessing the quality of ore raw materials allows us to obtain the relevant background for long-term strategic decision making. In the case of its use in electronic form, this principle can be applied for the operational comparison of purchased raw materials. Changing the number of criteria, changing the weighing system, or further adjusting the input parameters, are then user-friendly. Applying a used rating system can help increase the efficiency of the purchasing process and reduce costs in metallurgical organizations.

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