Abstract

Blast furnace procedure is a set of a large number of physical and chemical, thermal and mechanical processes, which do not take place separately, but are rather in certain mutual relation. The flow and the efficiency of the blast furnace process can be significantly affected by the quality of the input raw materials, which can be evaluated using a number of different criteria. That is why the selection and evaluation of the suppliers of strategic resources play very important role. Metallurgical enterprises must often compare and evaluate dozens of offers and they must monitor a number of regular and irregular suppliers. The evaluation of the suppliers of raw materials for metallurgical production can be realized in different ways. Most of the methods are based on monitoring the pre-defined criteria. During the decision-making itself, it is possible to consider a number of criteria related to the offered raw materials and services, in particular their quality, price and the contract terms. In practice, however, the number of the monitored criteria is usually limited to those that have certain weight in terms of the specific technological conditions of the company. Their selection must naturally be considered very carefully. The definition of importance of the individual criteria represents a key aspect in the evaluation. This will always be subjective to some extent. To define the weights of the individual criteria, it is possible to use the methods that reduce the subjective nature of the decision-making process. The article deals with the analysis of current approaches in the evaluation of suppliers in the area of metallurgical production. At the same time, it analyzes the possible utilization of the methods of distance from a hypothetical option and the methods of pair comparisons in the evaluation of the suppliers of input raw materials for metallurgical production.

Keywords: iron, steel, costs, suppliers

1. INTRODUCTION

The selection and evaluation of suppliers can be realized in various ways. Most of them are, however, based on monitoring of isolated criteria [1]. The actual decision-making process can take into consideration a number of criteria that affect the offered products and services, in particular their quality, price and the terms of contract. In practice, however, the number of the monitored criteria was usually limited to those having certain weight in terms of the specific conditions of the company [2]. Their selection must naturally be carefully considered. Industrial companies tend to favour those that affect the economic and business results of the company (costs, inventory, and quality). These criteria then naturally determine the final product quality [3]. It is also necessary to take into account the volume of purchase from the given supplier, i.e. its financial and economic importance. The experience with the given supplier represents an important factor as well. In general, the criteria can be divided into four groups [4]:

- criteria related to products;
- criteria related to provided services;
- criteria related to price and terms of contract;
- criteria evaluating the behaviour and attitude of the supplier.

When a difficult decision has to be taken, it is possible to select either one or several suppliers. It is often better to prefer purchasing from multiple sources, which eliminates the dependence on a single supplier and, in addition, it provides the possibility of comparison [5]. In case of repeated purchases, it is recommended to reconsider the decision regarding the selection of the supplier on the basis of updated information supplemented by the comparison of new purchasing options and experience. The purchasing decision-making should distinguish two groups of suppliers. The first step should be to forecast demand and sales to the end users of the chain [6]. The first group consists of smaller regional suppliers. Even smaller orders may be important for these companies. These suppliers put maximum effort to satisfying the agreed orders, because they do not want to lose their customer or their credit in competition with other potential partners [7]. The second group consists of large suppliers who are able to deliver, often flexibly, fairly wide range of products, but sometimes they expect more activity from the buyer or concessions in quality parameters. When deciding on the supplier, the decision can be a result of (according to the availability of information and the importance of purchasing decision):

- expert estimate of a team or a responsible individual;
- point evaluation (simple or with valuation - weighing - significance of the individual criteria);
- consideration of the calculation outcomes of those factors that can be directly quantified, and the factors of indirect quantification of qualitative characteristics (through scoring or expert estimates);
- utilization of multi-criteria decision making methods;
- combination of previous approaches.

There may often be specific cases when a company is forced to buy the cheapest raw materials offered, due to difficult financial situation. The existence of subjective interests, when the purchasing clerk’s company acts under some kind of pressure, may cause another problem. It often leads to taking occasional decisions, when the purchasing clerk places emphasis on the personal benefit of the company [8]. That is why it is always beneficial to exclude these effects, as well as the consequences of intuitive decisions as much as possible.

The conventional evaluation models assume that the decision-making entity compares the alternatives according to a single monitoring criterion. The resolver has a wide range of methods to be used in these cases, which allow him to find optimal solutions without additional information from the resolver. All the information that is actually used for the solution may be part of the task. However, this principle is not applicable for example in the evaluation of ore raw materials. The decision-making process may include as many as dozens of different criteria. From this perspective, the principles of multi-criteria decision-making, which make it possible to compare the individual suppliers according to a number of different criteria, represent a very interesting group of methods. The tasks of multi-criteria decision-making are such decision-making tasks, where the consequences of the individual decisions are assessed according to multiple criteria. The solution of a multi-criteria decision-making task is a procedure whose application helps us to find the optimal state of the system, with respect to more than one considered criterion. The objective of this article is to assess the possible utilization of the multi-criteria methods for the evaluation of suppliers and their offers in the processes of metallurgical production.

2. PROBLEM FORMULATION

In the processes dealing with the selection and evaluation of suppliers, we encounter an obstacle in the form of overall evaluation. Companies can use dozens of different criteria during the actual evaluation, which is quite common, for example, in the production of pig iron, when the monitoring of quality of supplying partners is a very complex process. If several supplying companies are being evaluated simultaneously, the whole
process is even more demanding. In this case, we are talking about multi-criteria decision-making. Metallurgical enterprises use a number of criteria to evaluate their suppliers. Some of them, however, have higher weight than other in terms of priorities. In such cases, the evaluation system is based on the quantification of the weights assigned to the individual criteria. However, the importance (weight) of the individual criteria for the evaluation of suppliers is set in a very intuitive way. There are frequent situations when workers see the importance of the individual criteria quite differently, according to their specialization.

For such cases, it is useful to apply the methods that significantly reduce the intuitive nature of the allocated weights. These methods can be used in all levels of corporate hierarchy. If we talk about the utilization in case of strategic decisions, we can apply these methods exactly for the selection and evaluation of suppliers.

It is often necessary to compare several suppliers that are evaluated according to various criteria, for example the suppliers of iron ore. One of the possible procedures of evaluation is the application of the method of distance from an imaginary option. This method allows taking into account all the specific values of the criteria.

The principle of the method of distance from an imaginary option is to find the distances of the individual options from the so-called fixed option, which can be:

- the best option, i.e. the best values of all the criteria - then the best option is the one with the smallest distance from the imaginary option,
- the worst option, i.e. the worst values of the criteria – the optimal option is the one which is most distant from the imaginary option.

The biggest advantage of this method is undoubtedly the fact that it takes into account the differences between the concrete values of the individual criteria. In case of the evaluation of ore raw materials, it will depend not only on the order the ores are arranged in descending order according to a specific criterion, but also on the individual differences. This method also takes into account the individual values of each criterion and it uses the differences among them within the scope of the evaluation, by comparing them using their weights. The procedure used for determination of the preferential arrangement of options taking advantage of the method of determination of the distance from an imaginary option can be divided into the following five points:

- Setting the weights of the individual criteria ($v_i$).
- Determining the best values of the individual options.
  (in our case, the ideal option as a set of the best values from the point of view of the individual criteria ($x_i^*$))
- Determining the worst values of the individual options ($x_i^0$).
- Calculation of the distance of each option from an imaginary option ($D_j$) based on the formula:

$$D_j = \sqrt{\sum_{i=1}^{n} v_i \left( \frac{x_i^* - x_{ij}}{x_i^0 - x_i^*} \right)^2}$$

, where

- $v_i$ - weight,
- $x_i$ - value of each criteria from the point of view of the individual options,
- $x_i^*$ - the best consequence in relation to the $i$ - th criterion,
- $x_i^0$ - the worst consequence in relation to the $i$ - th criterion.
- Setting the order of options (the best option is the one with the shortest distance from the imaginary option \((D_i)\))

The total value of the distance from the imaginary option is essentially created by the sum of partial deviations from the ideal value of the criterion in question. The option with the lowest total value is the optimal one. Since the method allows taking into account the individual differences in the values of criteria, the optimal option can be the one, which is not the best in any criterion.

3. EXPERIMENTAL WORK

Three suppliers of electrodes for electric arc furnaces were evaluated in the monitored industrial company. The suppliers were evaluated according to three criteria: price, delivery time and quality (table 1). All the monitored criteria are of different character, so it is difficult to determine the best option without using the multi-criteria methods. The best values of each criterion are marked green in Table 1. For the purpose of simplification, the suppliers will be identified by the letter D and the relevant number and criteria will use the symbol of K.

Table 1 Values of the individual offers

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Supplier - 1</th>
<th>Supplier - 2</th>
<th>Supplier – 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery time (days)</td>
<td>45</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Price ($ / kg)</td>
<td>19</td>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>Quality (1-10)</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

The method of the distance from an imaginary option was used to evaluate the monitored parameters. Equation (1) was used to determine the distance from the optimal option for all the suppliers. An example of calculation for supplier 2 can be written the following way:

\[
K_1 - D_2 = 0.300 \times \left( \frac{14-18}{45-14} \right)^2 = 0.005
\]

\[
K_2 - D_2 = 0.400 \times \left( \frac{19-20}{19-32} \right)^2 = 0.002
\]

\[
K_3 - D_2 = 0.300 \times \left( \frac{2-3}{2-4} \right)^2 = 0.075
\]

The individual values represent an imaginary distance from the ideal value of each criterion. The total value then equals the sum of all the individual parts. Similar method was used to determine the distance from an imaginary option for the other suppliers. The results are shown in Table 2. The determined value of the distance from an imaginary option is shown in line \(D_j\). At the same time, the table shows the total evaluation, which identifies the determined order of the individual suppliers.
Table 2 Evaluation of monitored offers

<table>
<thead>
<tr>
<th>$v_i$</th>
<th>$x_i^*$</th>
<th>$x_i^0$</th>
<th>$D_1$</th>
<th>$D_2$</th>
<th>$D_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_1$</td>
<td>0,300</td>
<td>14</td>
<td>45</td>
<td>0,300</td>
<td>0,005</td>
</tr>
<tr>
<td>$K_2$</td>
<td>0,400</td>
<td>19</td>
<td>32</td>
<td>0</td>
<td>0,002</td>
</tr>
<tr>
<td>$K_3$</td>
<td>0,300</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0,075</td>
</tr>
<tr>
<td>$\Sigma$</td>
<td>0,300</td>
<td></td>
<td>0,082</td>
<td></td>
<td>0,700</td>
</tr>
<tr>
<td>$D_j$</td>
<td>0,547</td>
<td></td>
<td>0,286</td>
<td></td>
<td>0,836</td>
</tr>
</tbody>
</table>

The options with the lowest value of the determined imaginary distance can be considered as the best ones. Thanks to this fact, the resulting sequence of the evaluated suppliers of electrodes is: Supplier 2, Supplier 1, and Supplier 3. If we look at the concrete value of the distance from an imaginary option, we can see that Supplier 2 receives significantly better evaluation. The obtained value is more than three times better than option 3. That is why this offer is by far the best. It is also necessary to mention that the offer of this supplier was not the best in any of the three monitored criteria, but despite that, it was evaluated as the best one by a large margin. This order of offers determined in this way is based on the quantification of all the monitored criteria.

4. CONCLUSIONS

The evaluation of suppliers in the sphere of primary and secondary metallurgy is complicated due to the wide spectrum of monitored criteria. If you want to find the most suitable option, it is very convenient to use methods that are able to take into account all the relevant criteria, although their character is entirely non-homogenous. Current approaches regarding the evaluation of suppliers and their offers are generally based on monitoring of isolated criteria, usually of economic nature. However, this system is not able to provide quality information about the real value of offers. It is therefore very convenient for the evaluation of the suppliers of input sources of primary and secondary metallurgy to use the mathematical methods of multi-criteria decision-making. An evaluation of offers for the given commodity from several suppliers was conducted within the frame of the monitored production enterprise. The conducted analysis has shown that the optimal selected option was the one that was not the best in any of the observed criteria. This means that if we made the evaluation using only one isolated criterion, we would not find the optimal option. The utilization of the mathematical methods in the evaluation of suppliers and the input raw materials in metallurgical processes seems to be a very suitable alternative. This is also given by the number of parameters to be monitored for the input raw materials. If we simultaneously consider the potentially wide range of suppliers, finding the optimal option without multi-criteria methods will be very difficult. When the methods of multi-criteria decision-making are applied, it is especially beneficial to use particularly those tools that will allow not only determining the best option, but also measuring the differences between them and determining their order as well. There may be frequent situations when the best determined option can not be used for certain reasons (technological, long-term contracts). The requirements for continuous reduction of production costs will force metallurgical companies to look for potential reserves in their processes. A precise and exact comparison of the individual commercial offers for the acquisition of the input raw materials, but also the evaluation of cooperation with long-term suppliers can bring substantial economic effect to metallurgical enterprises.
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REFERENCES


