Application of SELBESTTRA Software for choosing a Transportation System for Mineral Raw Materials through Special Protection Areas

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Abstract. The software package SELBESTTRA offers a choice of the best transportation systems of mineral resources with technical, economic and ecological point of view. By entering of parameters of production and the parameters of the proposed transportation route, the software gives us the best solution regarding the protection of environment through which transport is carried out and that for the best variant from techno-economic standpoint. By Changing of input parameters, we can control output data in order to obtain the best solutions in terms of requirements of investor.

Introduction

The generally accepted traditional method of selecting a transportation system is based on the techno-economic analysis, i.e. on defining the height of investment for the procurement of such a system that is satisfactory for its technical characteristics. At the same time, the following parameters, which are indispensable factors in the modern industry, are not taken into account: the environmental pollution by the adopted transportation system [1].

The SELBESTTRA software is based on the principle of the model, which, in addition to technical and economic indicators, evaluates environmental factors, and the output is the solution that meets all the criteria of a modern design technological system and that is technologically optimal, cost-effective and environmentally sustainable.

Basic features of the SELBESTTRA software

The software package SELBESTTRA (SELection of BEST TRA nsportation system) offers the possibility of selecting the optimal transportation system with regard to meeting technical and technological requirements of the exploitation process and the optimal economic parameters, while respecting the principles of the environmental protection [2].

Applied methodology of calculation

In order to select the most convenient method of mineral raw material transportation through the environment, it is necessary to determine a model that will avoid, to the maximum extent possible, a subjective influence of decision-makers.

In selecting a method of transportation, in general, the usual procedure is to search for a solution by considering a number of possible variants. Thereat decision-makers usually decide, depending on the required degree of precision, on the basis of the results from the following types of analysis:

\begin{itemize}
  \item techno-economic, and
  \item multi-criteria analysis.
\end{itemize}

In case of applying the multi-criteria decision-making, the results of the techno-economic analysis have the treatment of one of the criteria.

For making a decision on actions, where there are many alternatives, the best methods are the ones of Multi-Criteria Analysis (MCA) as a method of “higher rank”, widely applicable with a high practical significance [2]. In this model was used next methods:
1. **Simple Additive Weight method** - where selecting the best alternative is made by applying the following relation:

$$a^* = \left\{ \frac{\max^n \sum_{j} t_{ij}}{\sum_j t_j} \right\}_{i=1}^m , \quad j=1^n$$

$$\sum_j t_j$$

$a_i$ – available alternatives in the model, $i=1^m$

t$_j$ – vector of the criterion weight coefficients, $j=1^n$

$l_{ij}$ – elements of the linearized decision-making matrix, $i=1^m , \quad j=1^n$

2. **ELECTRE** method compares actions in pairs and searches for a level of concordance between preference weights and paired dominance correlations among certain actions, and then it examines the level of discordance, which represents the difference in evaluations of weights of certain actions [3].

Defining of concordance matrix and discordance matrix is made by applying the following relation:

Concordance matrix: $MS_{pr} = \sum_{j \in S_{pr}} t_j$

Discordance matrix: $MNS_{pr} = \frac{\max|t_{nprj} - t_{nj}|}{\max|t_{nprj} - t_{nrj}|}$

Defining input parameters. Input values for the selection of the optimal transportation system for mineral raw materials by applying the SELBESTTRA software are as follows: basic production parameters, conveying route parameters and environmental indicators. A condition for a quality and reliable calculation is to properly select and correctly enter the input parameters. For this reason the requirements for entering input parameters in the software are clearly defined, so that a user does not have any dilemmas when entering the appropriate data. The model is designed in such a way that the best solutions, with regard to technical requirements of the transportation, are obtained in the first step. The outputs of the technical block represent input parameters for the economic block and the calculation of economic indicators. The solutions with the optimal economic indicators - total capital investments and the transportation unit cost – enter in the evaluation system by multi-criteria-decision-making methods, along with environmental factors. The application of the software results in the best transportation method from point A to point B, which should meet the given requirements: to be technically viable, safe, reliable, cost-effective and with a highest level of the environmental protection [4,5,6].

Example of applying the SELBESTTRA software in the Mine Ćelije. The calcite deposit Ćelije is situated in the Southern Serbia, on the North-West slopes of the mountain Suva Planina at the altitude of about 1000 m. The calcite deposit is a very rich one, with a high content of CaCO3 (99.60% of CaCO3) and with a very low content of harmful components. The total reserves amount to over one million tons, whereby this deposit represents a very rich deposit of calcite.
Calcite is widely applied in many industries. The largest consumers of the calcite are: Refractory Industry, Ferrous Metallurgy, Construction material industry, Production of thermal insulating materials, Chemical and Pharmaceutical industry, Industry of rubber, paper, leather, ceramics, Water industry and Agriculture.

The Calcite deposit Ćelije is located in the area of the protected natural resource (Fig. 1). According to the Law on the natural protection of the Republic of Serbia, in these areas any kind of pollution and terrain degradation is prohibited. For that reason, the investor opted for underground mining of this raw material. Thus, a direct contact with the nature and living world surrounding the mine is avoided.

The Plant for calcite preparation is located at a distance of about 3 km (in a straight line) from the mine. Such position of the mine and the preparation plant conditions the route of the external transportation for mineral raw materials, which will be fully carried out in the area of the protected natural resource, which means that raw material will need to be transported from the mine to the plant through the protected area. In addition, the terrain is inaccessible and very steep, which excludes the application of truck transportation.

Considering technical and technological characteristics of a mining system, and topographic and environmental characteristics of the area where mining, transportation and preparation of raw materials will be carried out, belt conveyors with protective corridor and pipe conveyors were selected as optimal solutions. The decisive factor would naturally be the economic factor, which has to meet the lowest investments criterion and the criterion of the lowest transportation cost per unit of the transported load. The innovation in the approach to selecting the optimal transportation system, which SELBESTTRA offers, is that the environment, as a proper factor, is included with all its qualitative indicators.

The parameters of the route and the mine work organization are as follows: the work is performed in one shift, 5 working days a week and with the annual capacity ranging from 15,000 m$^3$ to 60,000 m$^3$. The mine is at the altitude of 1007 m, and the preparation plant at the altitude of 504 m.

For evaluating the environmental parameters it is necessary to define categories of the environments through which the route passes and the lengths of route sections that are situated in the corresponding environment. The software offers the choice between five categories of the environments through which the transportation is carried out. In the case of the mine Ćelije, the transportation is carried out, in its entire length, through the special protection area.

The conveying route is defined on the basis of the terrain configuration and technological parameters of the transportation system. Considering that pipe conveyors can operate at the incline up to 40°, the route determined for this type of the transportation will be much shorter than the one proposed for standard belt conveyors at the maximum incline angle of 18° [7,8].

The Fig. 1 shows the proposed conveying routes for pipe conveyors (red line) and belt conveyors (green line). The route for truck transportation is marked in yellow, for the purpose of comparison with other solutions. For the route of truck transportation the existing roads were mostly used. The data necessary for defining the system are obtained by entering the production parameters and conveying routes parameters. For belt conveyors the following output data are obtained: conveyor belt width, number of belt plies, breaking strength of a ply, belt speed, total transportation costs per load unit, length of one conveyor in the system, number of conveyors in the system, required power of the drive motor, system security coefficient and total capital investments. For pipe conveyors the output data are as follows: pipe diameter, belt width, belt speed, maximum diameter of a piece to be transported, total costs per load unit, hourly capacity of a conveyor (as in the catalogue), length of one conveyor, number of conveyors, required motor power, security coefficient and total capital investments. Despite the fact that there are some theoretical calculations based on a standards it is common in the industry that the belt is not properly selected or it is overdesigned or number of its types is too large what can lead to increased costs for its storage [9].
After analysing the output data on the optimal transportation system, offered by SELBESTTRA, a decision-maker can go back to the beginning of the program and correct input data, and thus control the final solution until the satisfactory and acceptable results are obtained.

In case of the mine Ćelije, it is necessary to define the annual production capacity out of the conditions of the lowest unit transportation price. Thereby the selected production parameters and transportation system would have the best economic and environmental parameters.

The table below shows unit prices of transportation for different capacities of calcite production in the Mine Ćelije, obtained by applying the SELBESTTRA software.

<table>
<thead>
<tr>
<th>KAPACITET PROIZVODNJE (m$^3$/god)</th>
<th>15.000</th>
<th>20.000</th>
<th>25.000</th>
<th>30.000</th>
<th>35.000</th>
<th>40.000</th>
<th>45.000</th>
<th>50.000</th>
<th>55.000</th>
<th>60.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>conv. belt</td>
<td>44.08</td>
<td>35.04</td>
<td>28.11</td>
<td>24.80</td>
<td>21.30</td>
<td>20.45</td>
<td>18.19</td>
<td>16.39</td>
<td>14.92</td>
<td>12.71</td>
</tr>
<tr>
<td>pipe conv.</td>
<td>62.39</td>
<td>46.79</td>
<td>37.43</td>
<td>31.20</td>
<td>26.74</td>
<td>23.40</td>
<td>20.80</td>
<td>18.72</td>
<td>17.02</td>
<td>15.60</td>
</tr>
</tbody>
</table>

We can conclude from the diagram (Fig. 2) that transportation cost decreases with the increase of capacity. If we take into account that, on the basis of empirical data, it is reasonable to expect that the share of transportation cost in the unit price of raw material amounts up to 30% in the market, then the cost-effectiveness margin of transportation cost, in this particular case, is about 40 €.

Due to the given parameter, the marginal production capacity can be read from the diagram, which should not be, in this case, lower than 16.500 m$^3$ when belt conveyors are applied and 23.000 m$^3$ when pipe conveyors are applied.

Considering that the SELBESTTRA software proposes pipe conveyors as the best solution of transportation system, by the primary method – ELECTRE, and by the control method – SAW (Simple Additive Weighting method), we can conclude that, from the technical, economic and environmental aspect, pipe conveyors are the best solution for transportation in the Calcite Mine Ćelije, with the annual mine production capacity of minimum 23.000 m$^3$. 

![Fig. 1 An outline of conveying routes](image1)

![Fig. 2 Diagram of dependency of transportation unit price of on production capacity](image2)
Summary

By applying the SELBESTTRA software for the selection of an optimal transportation system, we obtain the solutions, from technical, economic and environmental aspect, for the transportation of raw materials in an area of specially protected natural resource, which are technologically satisfactory, economically optimal and environmentally acceptable. After analysing the obtained data, and opting for the appropriate economic indicators, a decision-maker has the possibility to obtain, for the given conditions of cost-effectiveness, the best solution for the transportation system through protected natural environment.

References


