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Professional paper

APPLICATION OF THE AHP METHOD FOR SELECTION OF A TRANSPORTATION SYSTEM IN MINE PLANNING

Despodov Zoran[1], Mitić Saša[2], Peltečki Dragi[3]

Abstract: The Analytic Hierarchy Processes method (AHP), as a mathematical method, is commonly used in resolving mining problems. The method is based on the Multicriteria decision making principle where the most suitable alternative is selected out of a group of available alternatives on the basis of a defined number of decision making criteria. This method is particularly suitable for use in cases when there is not enough information on the reviewed alternatives in the decision making. This paper identifies the application of the AHP method in the selection of an optimal transportation system in a main haul corridor.

Key words: AHP method, alternatives, decision making, underground transport

1. INTRODUCTION

The Analytic Hierarchy Process method (AHP) was developed by Thomas Saaty in the beginning of 1870′s and it represents a tool in the decision making analysis. It was designed to assist the planners in resolving complex decision making problems where a large number of planners participate, and a number of criteria exist in a number of specific time periods.

The area of application of the AHP method is the Multicriteria decision making where, on the basis of a defined group of criteria and attribute values for each alternative, the selection of the most acceptable solution is done, i.e. the complete layout of alternative importance within the model is presented. For the purposes of an easier method application, specific decision making support software Expert Choice has been developed for the specific example. In addition, four phases of method application have been noticed (Čupić and Suknović, 1995):

1) Problem structuring,
2) Data collection,
3) Relative weight evaluation,
4) Problem solution establishment.

Problem structuring consists of decomposing a certain complex problem of decision making into a series of hierarchies where each level represents a smaller number of managed attributes. The problem structuring graphics is presented on Figure 1.

[1] "Goce Delčev" University - Štip, Faculty of natural and technical sciences – Mining institute, Krste Misirkov bb, 2000 Štip, R.Macedonia, e-mail: zoran.despodov@ugd.edu.mk
[2] Mining Institute Belgrade, Batajnički put 2, 11080 Zemun, Serbia, e-mail: podzemna@ri.beograd.ac.rs
[3] Rudplan DOOEL, Atanas Karaman 36, 2400 Strumica, R.Macedonia, e-mail: dragip@rudplan.com.mk

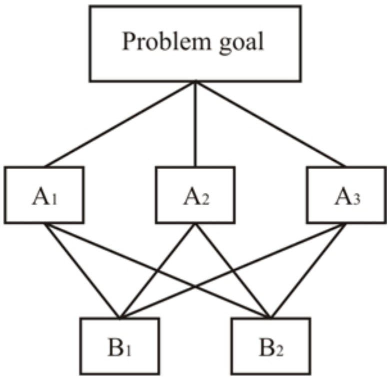

Figure 1 - Problem structuring

By collecting the data and its calculation, the second phase of AHP starts. The decision maker assigns relative weight to pairs of attributes of a single hierarchy level, for all levels of the hierarchy. In addition, the most common nine-point scale is used, presented in Table 1.

Table 1 - Nine-point scale

Scale	Ranking	Explanation
1	Equally important	Both criteria or alternatives contribute to the objective equally
3	Moderately important	Based on experience and estimation, moderate preference is given to one criteria or alternative over the other
5	Strictly more important	Based on experience and estimation, strict preference is given to one criteria or alternative over the other
7	Very strict, proven importance	One criteria or alternative is strictly preferred over the other; its dominance has been proven in practice
9	Extreme importance	The evidence based on which one criteria or alternative is preferred over the other has been confirmed to the highest confidence
2; 4; 6; 8	Mid-values	

After this phase has been completed, the corresponding pairwise comparison matrix is obtained, corresponding to each level of hierarchy.

Determining the relative weight is the third phase of the AHP method application. Pairwise matrix, by pairs, "transfers" into problems of own values determination in order to get the normalized and single eigen vectors, as well as the weight of all attribute on each hierarchy level $A_1, A_2, ..., A_n$, with a weight vector $t = (t_1, t_2, ..., t_n)$.

Problem resolution is the last phase of the AHP method and it involves the establishment of the so-called composite normalized vector. After the vector of criteria activity layout in the model is established, the next round involves the determination of alternative importance in the model, within each criteria. In the end, the total problem synthesis is carried out in the following way: the weight of each criterion is multiplied by the weight of the reviewed criterion, and these values are then summarized for each alternative separately. The result is the weight of the reviewed alternative within the model. The weight of all of the rest alternatives is calculated in the same way. After that, the final ranking of alternatives in the model is determined.

2. CONSISTENCY

The AHP method belongs to the group of popular methods for its possibility of identification and analysis of the consistency of decision maker in the process of comparison of elements in the hierarchy. Considering that the alternative comparison is based on a subjective estimation by the decision maker, it is necessary that it is constantly monitored in order to secure the required accuracy (Samanta and Mukherjee, 2002).

The AHP method ensures that the evaluation consistency is monitored constantly in the alternative pairwise comparison procedure. The consistency index

$$C.I. = (\lambda_{max} - n)/(n-1) \quad (1)$$

calculates the consistency ratio $C.R. = C.I./R.I.$, where $R.I.$ is the random consistency index (n size matrix consistency index of randomly generated pairwise comparison, for which table 2 is used (with calculated values):

Table 2 - Random consistency index values *R.I.* (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

λ_{max} is the matrix Eigen value, whereas n is the matrix size. Thereto, it is true that $\lambda \geq n$, and the difference $\lambda_{max} - n$ is used to measure the evaluation consistency. In case of inconsistency, if λ_{max} is closer to n, the evaluation is more consistent.

If $C.R. \leq 0.10$, the calculation of relative criteria importance (alternative priority) is considered acceptable. In the opposite case, the decision maker has to analyze the reasons for unacceptably high evaluation inconsistency.

3. SELECTION OF AN UNDERGROUND TRANSPORTATION SYSTEM

In the planning phase of the opening of the new lead and zinc deposit, it is projected that a main haul corridor is built which is to be used for ore transportation from the central ore chute located underground to the flotation bunker located at the surface. The corridor is 1,800 m long with a high arc cross-section; the area of the cross section is 11 m^2. The annual ore quantity that is transported through the main haul corridor amounts to 750,000 tones. The decision maker – the planner – is assigned to select the optimal underground transportation system out of several available alternatives.

The problem of selection of the transportation system in the main haul corridor has been defined in the following way:

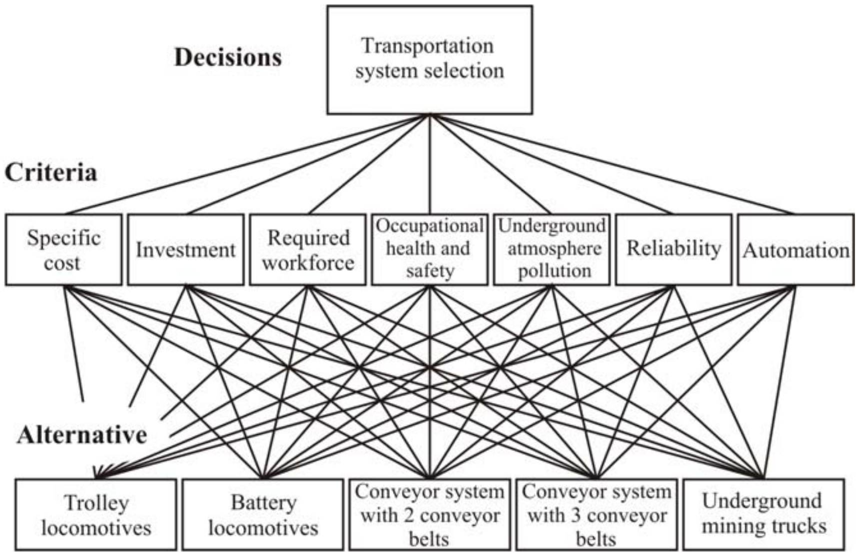

Figure 2 - Structuring the problem of selection of the transportation system in the main haul corridor

The second level attributes (decision criteria) are marked in the following way:
A_1 - specific transportation system cost,
A_2 - total investment,
A_3 - required workforce,
A_4 - transportation system safety,
A_5 - underground air pollution,
A_6 - transportation system reliability,
A_7 - transportation system automation.

Next, the importance of attributes could be assigned as presented in the next table, i.e. the table of comparison:

Table 3 - First level attributes comparison (decision criteria)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	Weight
A_1	1	7	7	5	6	7	7	0.4923
A_2	0.14	1	1	3	2	1	1	0.0944
A_3	0.14	1	1	3	7	1	1	0.1292
A_4	0.20	0.33	0.33	1	0.50	0.33	0.33	0.0414
A_5	0.17	0.50	0.14	2	1	0.50	0.50	0.0536
A_6	0.14	1	1	3	2	1	1	0.0944
A_7	0.14	1	1	3	2	1	1	0.0944

$$\lambda_{\max} = 7.7140; \quad C.I. = 0.1190; \quad C.R. = 0.0881 < 0,10$$

Analogously, the third level attributes (alternatives) could be marked in the following way:
B_1 - transportation system with trolley locomotives,
B_2 - transportation system with battery locomotives,
B_3 - transportation system with 2 conveyor belts,
B_4 - transportation system with 3 conveyor belts,
B_5 - transportation system with underground mining trucks.

The corresponding third level alternative comparison matrices for each attribute and their respective priorities are presented in Tables 4-10:

Table 4 - Matrix of alternative relative importance compared to A_1 attribute (specific cost)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	2	0.33	0.50	3	0.1729
B_2	0.50	1	0.33	0.50	2	0.1194
B_3	3	3	1	2	4	0.3953
B_4	2	2	0.50	1	3	0.2394
B_5	0.33	0.50	0.25	0.33	1	0.0728

$$\lambda_{max} = 5.1325; \quad C.I. = 0.0331; \quad C.R. = 0.0298 < 0{,}10$$

Table 5 - Matrix of alternative relative importance compared to A_2 attribute (investment)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	0.50	2	3	0.14	0.1105
B_2	2	1	2	3	0.14	0.1397
B_3	0.50	0.50	1	2	0.13	0.0740
B_4	0.33	0.33	0.50	1	0.11	0.0466
B_5	7	7	8	9	1	0.6294

$$\lambda_{max} = 5.2892; \quad C.I. = 0.0723; \quad C.R. = 0.0651 < 0{,}10$$

Table 6 - Matrix of alternative relative importance compared to A_3 attribute (required workforce)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	3	0.20	0.25	0.16	0.0627
B_2	0.33	1	0.13	0.17	0.20	0.0324
B_3	5	7.70	1	2	0.33	0.2319
B_4	4	5.90	0.50	1	0.16	0.1440
B_5	6	5	3	6	1	0.5287

$$\lambda_{max} = 5.2141; \quad C.I. = 0.0535; \quad C.R. = 0.0482 < 0{,}10$$

Table 7 - Matrix of alternative relative importance compared to A_4 attribute (safety)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	0.50	0.20	0.25	2	0.0796
B_2	2	1	0.17	0.20	2	0.0975
B_3	5	6	1	2	7	0.4600
B_4	4	5	0.50	1	6	0.3120
B_5	0.50	0.50	0.14	0.17	1	0.0501

$$\lambda_{max} = 5.2223; \quad C.I. = 0.0555; \quad C.R. = 0.0500 < 0{,}10$$

Table 8 - Matrix of alternative relative importance compared to A_5 attribute (air pollution)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	2	0.33	3	4	0.2607
B_2	0.50	1	0.33	0.50	3	0.1255
B_3	3	3	1	2	5	0.3905
B_4	0.33	2	0.50	1	4	0.1773
B_5	0.25	0.33	0.20	0.25	1	0.0458

$$\lambda_{\max} = 5.2685; \quad C.I. = 0.0671; \quad C.R. = 0.0604 < 0,10$$

Table 9 - Matrix of alternative relative importance compared to A_6 attribute (reliability)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	4	0.25	0.33	2	0.1417
B_2	0.25	1	0.20	0.25	2	0.0742
B_3	4	5	1	2	7	0.4405
B_4	3	4	0.50	1	6	0.2915
B_5	0.50	0.50	0.14	0.17	1	0.0519

$$\lambda_{\max} = 5,2648; \quad C.I. = 0,0662; \quad C.R. = 0,0596 < 0,10$$

Table 10 - Matrix of alternative relative importance compared to A_7 attribute (automation)

	B_1	B_2	B_3	B_4	B_5	Weight
B_1	1	3	0.20	3	3	0.1944
B_2	0.33	1	0.16	0.20	2	0.0578
B_3	5	6	1	2	6	0.4917
B_4	0.33	5	0.50	1	7	0.2153
B_5	0.33	0.50	0.16	0.14	1	0.0406

$$\lambda_{\max} = 5.3868; \quad C.I. = 0.0967; \quad C.R. = 0.0871 < 0,10$$

At the end of the procedure, a total problem analysis of the underground transportation system selection is done, so that all alternatives are multiplied by the weight of the single decision criteria, and the results obtained are summarized. The alternative with the highest value is, in fact, the most acceptable or optimal alternative. The last procedure of the AHP method application is presented in Table 11.

Table 11 - Synthesized table on the optimal alternative selection

Criterion	Criter. weight	B_1	Weight x B_1	B_2	Weight x B_2	B_3	Weight x B_3	B_4	Weight x B_4	B_5	Weight x B_5
A_1	0.4923	0.1729	0.0851	0.1194	0.0588	0.3953	0.1946	0.2394	0.1179	0.0728	0.0358
A_2	0.0944	0.1105	0.0104	0.1397	0.0132	0.0740	0.0070	0.0466	0.0044	0.6294	0.0594
A_3	0.1292	0.0627	0.0081	0.0324	0.0042	0.2319	0.0300	0.1440	0.0186	0.5287	0.0683
A_4	0.0414	0.0796	0.0033	0.0975	0.0040	0.4600	0.0190	0.3120	0.0129	0.0501	0.0021
A_5	0.0536	0.2607	0.0140	0.1255	0.0067	0.3905	0.0209	0.1773	0.0095	0.0458	0.0025
A_6	0.0944	0.1417	0.0134	0.0742	0.0070	0.4405	0.0416	0.2915	0.0275	0.0519	0.0049
A_7	0.0944	0.1944	0.0184	0.0578	0.0055	0.4917	0.0464	0.2153	0.0203	0.0406	0.0038
			0.1526		**0.0994**		**0.3595**		**0.2111**		**0.1768**

4. CONCLUSION

This paper identifies the application of the AHP method in the process of selection of transportation system in a lead and zinc mine, during the planning phase. One of the major problems in the application of this method is the determining of the second level decision attributes (decision criteria) and the evaluation of their relative weight. The authors of the paper have defined the criteria and evaluated their relative weight values on the basis of their own experience and previous scientific research.

The precise implementation of procedure in the application of the AHP method results in getting the largest total value (0.3595) for the third alternative; hence, it is the most suitable alternative in the procedure for transportation system selection for the main haul corridor.

The decision maker – the planner – has to adopt a solution – alternative for ore transportation with hanging transporter composed of two sections. The raw material and workforce transportation could be carried out with self-propelled diesel transportation means.

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