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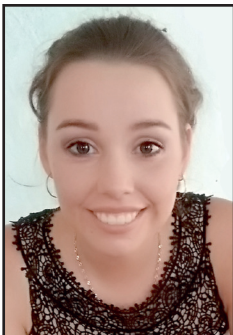
Decision-Making on Choosing a Railway Line Option



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ABSTRACT

This article proposes a solution to the problem of choosing an option for routing of a railway line among two previously developed options. As initial data, materials were used for designing Elegest–Kyzyl–Kuragino railway line.

On this section, two routing options are considered, which must be compared in order to choose the best one. The first option of the line (Eastern) takes place in a recess outside the village of Podgorny, which excludes the cost of demolition of residential buildings and relocation of residents, but provides for a large amount of earthwork. In the second option (Western), the line is laid through the village of Podgorny. With this development of the line, the volume of earthwork is much smaller, but it is necessary to take into account demolition of residential buildings, relocation of residents, as well as installation of noise barriers.

The conclusion drawn by the designers of CJSC Vostsibtransproekt was reviewed and analyzed. During the study, the applied decision-making method required some refinement with regard to this problem and additional analysis. To select the best option, the analytic hierarchy process was used.

Keywords: *railways, decision-making, design of railways, analytic hierarchy process.*

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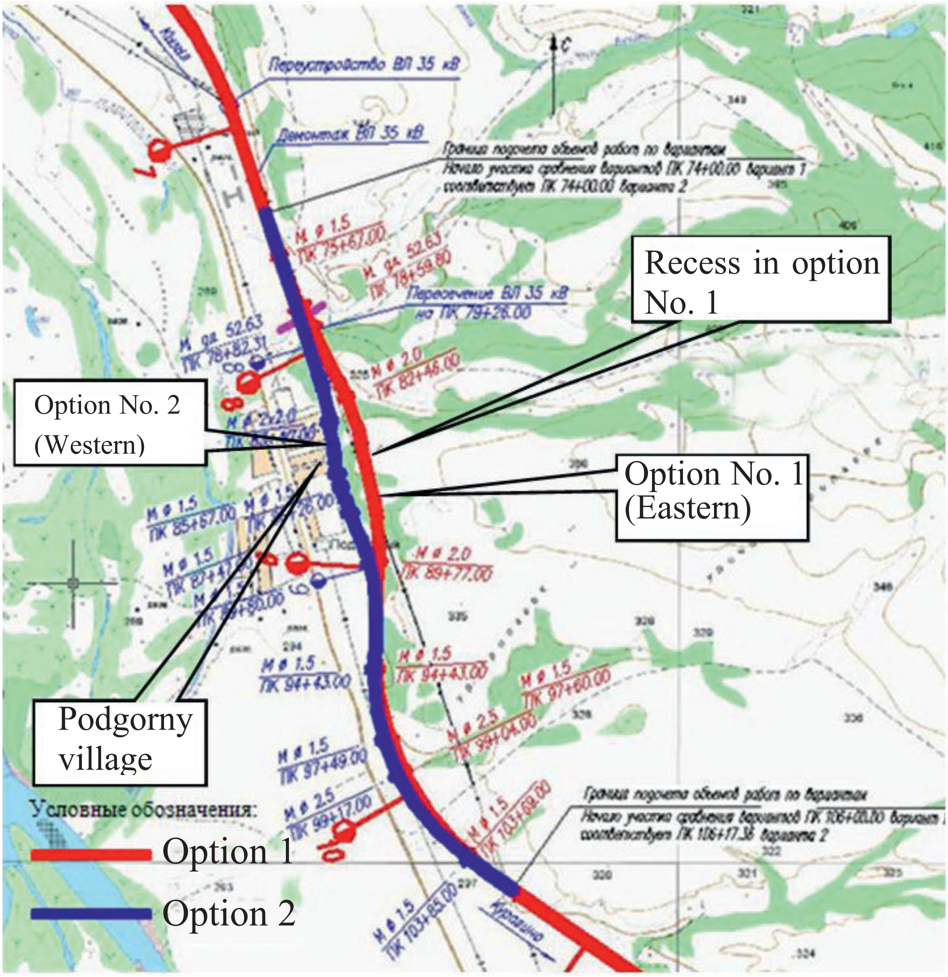


Pic. 1. Layout of the options for the section km 8–km 11. Option No. 1 (Eastern): the route is laid bypassing the village of Podgorny, it is shown in lighter (red) color. Option No. 2 (Western): the route is laid through the village of Podgorny, it is shown in darker (blue) color.

Introduction. The decision-making process in design of railways is quite complex, requiring not only a comprehensive study of the issue, but also a comprehensive look at the whole system [1, p. 5].

A significant role, in addition to technical indicators, is also played by economic factors, for example, by the cost of construction. Multiple solution options are formed, and while all of them comply with the requirements, it is still necessary to choose the best one among them [2, p. 209].

Of course, during the design process, some options can be eliminated, but a reduced set of options remains, and the decision-maker (DM) should still choose the best option among them [3, p. 56].

The *objective* of the research presented in the article was to develop a decision-making method when choosing a railway line routing based on the analytic hierarchy process of T. L. Saaty to formalize the preferences of DM.

The research was carried out with regard to the section of the designed railway line Elegest–Kyzyl–Kuragino. The data for the article was provided by CJSC Vostsibtransproekt (VSTP) [4, p. 37]. In our article, DM means not a single person, but a group of individuals (designers of CJSC VSTP, authors of the article).

The *methods* of decision theory were used, in particular methods for solving the multicriteria deterministic choice problem, the analytic hierarchy of T. L. Saaty, economic and technical analysis [5, p. 81; 6, p. 129; 7, p. 93; 8, p. 76].

Let's consider the mentioned section of the designed railway line Elegest–Kyzyl–Kuragino. For the section Kuragino–

Table 1

Comparison of options for a railway line on the section km 8–km 11

Indicators	Meas. unit	1 option PC74+00.00 – PC106+00.00	2 option PC74+00.00 – PC106+17.36
Length	l. m	3200	3217,36
Maximum gradient	‰	9	9
Specialized volume of earthwork	thous. m^3	870,56	266,54
including embankment	thous. m^3	142,68	208,33
including recess	thous. m^3	727,88	58,21
Cost of road bed, in prices of 01.01.2000	thous. rub.	9685,81	7393,73
Artificial structures:	pcs.	7	10
metal bridge	pcs./m	1/52,63	1/44,80
MGT Ø. 1.5 m	pcs.	3	6
MGT Ø. 2.0 m	pcs.	2	-
MGT Ø. 2.5 m	pcs.	1	2
MGT Ø. 2x2.0 m	pcs.	–	1
Cost of construction of artificial structures, in prices of 01.01.2000	thous. rub.	17715,16	18296,83
Demolition of buildings:			
residential houses	pcs./thous. rub.	–	5/26,45
water tower	pcs./thous. rub.	–	1/9,92
lines OPTL	km/thous. rub.	2,1/195,74	–
Compensation for demolition and construction:			
residential houses	thous. rub.	–	39,95
water supply system of a village	thous. rub.	–	121,86
reconstruction of OPTL	km/thous. rub.	2,2/782,96	–
reconstruction of a road-street network	km/thous. rub.	0,21/285,75	1,00/1542,20
arrangement of noise barriers	km/thous. rub.	0,26/939,12	0,61/2205,84
Total estimated cost of construction in prices of 01.01.2000	thous. rub.	29604,54	29636,78

Ermakovskaya (km 0–km 104), where the route passes through the valleys of the Tuba and Amyl rivers, the option of laying a route in the area bypassing the village of Podgorny at km 8–km 11 of the section is considered.

For the purpose of comparing local siting options, the designers of CJSC VSTP determined the following volume indicators within the common comparison points:

a) volume of earthwork by options;

b) volume of artificial structures: bridges, pipes;

c) demolition of buildings, overhead power transmission lines (OPTL);

d) compensation for demolition and construction of new facilities: reconstruction of OPTL, reconstruction of the road-street network, arrangement of crossings, arrangement of noise barriers (acoustic screens).

Comparison of routing options in the area of km 8–km 11

Within the area located at km 8–km 11 of the considered route, two routing options were subject to comparison (Pic. 1).

Description of the option No. 1 (Eastern)

The beginning of the route is at the picket (PC) 74+00.00; end of the route is at the PC106+00.00; its length according to this option is 3200,00 m.

The option was designed to bypass Podgorny village, the route runs in a recess, completely excluding demolition of residential buildings, and does not require reconstruction of a water tower and a water well.

At PC79+27 and PC87+33, the route crosses the 35 kV OPTL, which entails reconstruction of the 2,2 kV OPTL section. A set of measures for noise protection when laying a railway line in the sanitary zone of development provides for installation of noise barriers for a distance of 0,26 km. To some extent, the railway line route is located at a distance of 100–200 m from the housing development boundary in a recess up to 20 m deep, which does not require installation of acoustic screens.

Description of the option No. 2 (Western)

The beginning of the route is at PC74+00.00; the end of the route is at PC106+17.36/PC106+00.00; its length according to this option is 3217,36 m.

Option No. 2 was developed with the aim to eliminate significant volumes for development of the recess, which in option No. 1 are of more than 700 thousand m^3. The route passes through the territory of Podgorny village. At the same time, 5 residential buildings with outbuildings, as well as a water tower, fall under demolition. In addition, due to abandonment of arrangement of a recess, volumes for construction of noise barriers in the sanitary zone of housing development increase by 0,35 km.

Technical and economic indicators of the compared options are presented in Table 1.

The conclusion that was made by the designers of JSC VSTP

When comparing the main technical and economic indicators of the options, the designers of CJSC Vostsibtransproekt concluded that the options in terms of aggregate construction costs in accordance with the accepted calculation methods are equivalent. However, preference was given to option No. 1, as:

• costs of demolition of residential buildings are excluded;

• costs of resettlement of residents are excluded;

• reconstruction of a water tower and a water well is excluded;

• prevailing living conditions of the population in Podgorny village are preserved.

The project implemented the option of the route No. 1.

Proposal for improving the procedure for comparing options

Given the basic principles of decision-making theory, the comparison was the solution of a multi-criteria deterministic choice problem, which is quite acceptable, but requires some refinement by formalizing the preferences of DM [9, p. 77; 10, p. 248].

We have proposed to formalize the preferences of DM using the analytic hierarchy process of T. L. Saaty (AHP) [11, p. 183; 12, p. 196], which allows us to understand in a clear and rational way the complex decision-making problem in the form of a hierarchy, to compare and quantify alternative solutions.

Analysis of the decision-making problem in HAM begins with construction of a hierarchical structure, which includes the goal, criteria, alternatives, and other factors considered that influence the choice. This structure reflects the understanding of the problem by DM. The method of analyzing hierarchies might be subjective if a single person evaluates the criteria. In our research, subjectivity is partially overcome, since several experts with different professional experience participated in the assessment.

The next stage of analysis is focused on determination of priorities representing the relative importance or preference of the elements of the constructed hierarchical structure using the procedure of pairwise comparisons. Dimensionless priorities make it possible to reasonably compare heterogeneous factors, which is a hallmark of AHP. At the final stage of the analysis, a synthesis (linear convolution) of priorities on the hierarchy is performed, as a result of which the priorities of alternative solutions relative to the main goal are calculated.

For our task, the expert group selected the following criteria:

I – construction length (running meter);

II – on-site volume of earthwork (thous. m^3);

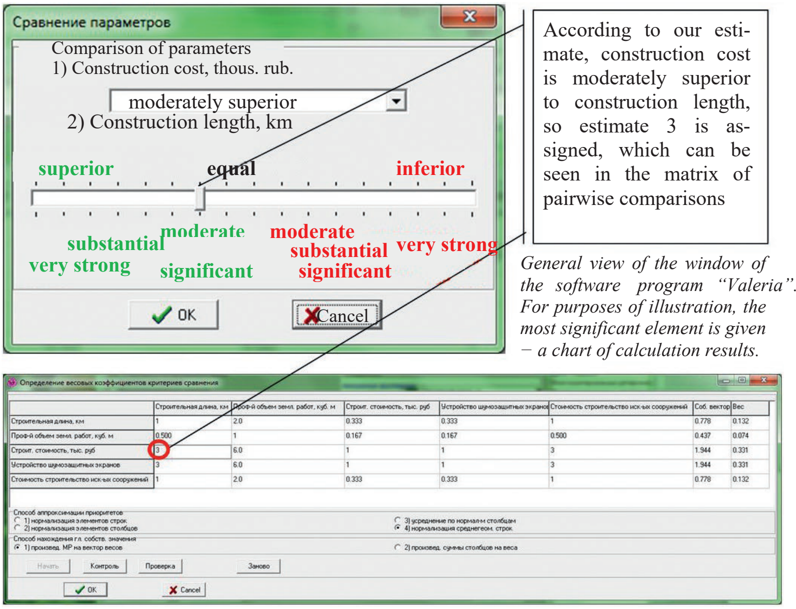
III – construction cost (thous. rub.);

IV – arrangement of noise barriers (km/thous. rub.);

V – cost of construction of artificial structures (thous. rub.).

Next, a matrix of pairwise comparisons of criteria by importance (using a nine-point scale) was compiled.

	I	II	III	IV	V
I	1	2	0,333	0,333	1
II	0,5	1	0,167	0,167	0,5
III	3	6	1	1	3



Pic. 2. The scale of assessment by the criterion «Construction cost, thous. rub., in the program «Valeria».

IV	3	6	1	1	3
V	1	2	0,333	0,333	1

At this stage, the estimates have the following meaning:

1 – equal importance of criteria;
3 –moderate superiority;
5 – significant superiority;
7 – substantial superiority;
9 – very strong superiority;
2, 4, 6, 8 – intermediate values.

The matrix is filled in line by line, starting with the most important criterion. First, integer estimates are put down, then the fractional estimates corresponding to them are obtained from them automatically (as inverse to integers). The more important the criterion is, the more integer estimates will be in the corresponding row of the matrix, and the estimates themselves will have larger values. Since each criterion is equal in importance, the main diagonal of the matrix will always consist of 1.

Then we calculate the geometric mean of each line according to the formula (1) and the components of the normalized priority vector (NPV) according to the formula (2):

$$a_n = \sqrt[n]{product\ of\ \ elements\ of\ n-th\ \ line}, \qquad (1)$$

$$n-th \text{ component of NPV} = \frac{a_n}{\sum a_i}. \qquad (2)$$

Next, we conduct a pairwise comparison of options by each criterion and determine the general criterion (priority) for each option. The best option is the one with the highest priority.

Automated calculation using «Valeria» program

An example of automation of calculations by the analytic hierarchy process of T. L. Saaty is «Valeria» decision support system (DSS) (author P. N. Kholodov, ISTU) [13].

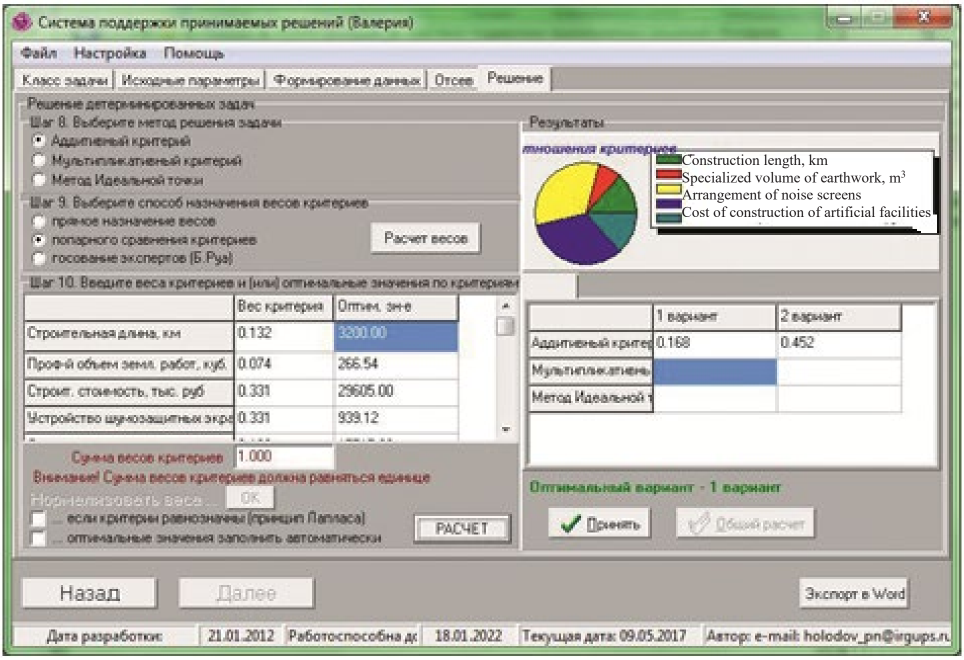
We will use «Valeria» software to solve the problem of choosing the routing option through bypass (option No. 1)/intersection (option No. 2) of Podgorny village within the area of km 8–km 11 of Kyzyl–Kuragino line being designed.

Estimates are assigned following a nine-point scale, as shown above (Pic. 2).

The advantage of «Valeria» DSS program is the fact that it is possible to solve the problem using different methods (Pic. 3).

After an additional analysis of the presented options, we have got the result that the first option is optimal, and that confirmed the conclusions drawn by the designers of VSTP.

Conclusions. In design of railways, the process of choosing of the best option may not always be simple and obvious. While having quite similar options for making the right decision, it is advisable not to rely exclusively



General view of the window of the work program «Valeria». For purposes of illustration, the most significant element is given: a chart of final ranking of obtained results.

Pic. 3. The calculation of the best option in DSS «Valeria».

on the analysis of technical and economic indicators. An additional comparison of options is needed. In our case, when solving the task set before us, we used the analytic hierarchy process, which confirmed the results obtained through the analysis of technical and economic indicators.

The method we used can be considered as promising and effective for solving problems of this kind, and not only when choosing options for the railway line routing.

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