Methodology for assessing the competitiveness of options for the direction of the projected railway using SWOT analysis

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Abstract. The article presents a method for assessing the competitiveness of options for the directions of the projected railway at the pre-project stage. The first stage of the method involves the formation of an initial set of alternatives to directions using graph theory. The proposed approach to the formation of options for directions guarantees the consideration of all possible options for connecting the reference points defined by the design assignment. The second stage deals with the formation of an acceptable set of these alternatives using the SWOT analysis, method the use of which allows both quantitatively and qualitatively to assess the impact of internal and external environmental factors on the design object, that is, to take into account the weaknesses and strengths of each direction option, opportunities and threats of the external environment. The fourth stage of the considered method involves the determination of the integrated indicators of economic efficiency recommended for further design options for the direction of the railway.

1. Introduction
The principal direction of the projected railway, as well as the main parameters of its design (limiting slope, length of receiving and sending tracks, type of traction, etc.), in accordance with current regulatory documents should be established based on the results of technical and economic calculations for the future. This should take into account the savings in initial costs and ensure a further stepwise increase in its capacity as the required volume of traffic increases.

The interrelation of the issues of choosing the direction of the railway and its main parameters, taking into account the prospects for developing the capacity of the projected line, emphasizes the exceptional importance of a well-founded determination of the principal (main) direction and its possible options.

In general, the choice of the direction of the projected railway is influenced by various socio-economic, natural, technical and other factors, which in some cases are interrelated.

Socio-economic factors include, first of all, the purpose of the projected line, the location of the main cargo and passenger-generating centers, the availability of existing transport infrastructure and its interconnection with the new railway, etc.

In project practice, socio-economic factors determine the position of strong points, the mandatory passage of the route of the projected line. In some cases, reference points (abutment station of the projected line, the end point) can be defined by the design task.

Topographical, geotechnical, hydrological, climatic, seismic, and other design conditions are natural factors. These factors are determined by the location of fixed points through which it is desirable to pass possible variants of the railway route.
Various combinations of connecting strong points and fixed points define a variety of options for the direction of the projected railway.

Evaluation of the competitiveness of the resulting set of options should be carried out taking into account technical factors, which primarily include the main design parameters: the limiting slope, the number of main paths, the type of traction, the length of the receiving and sending paths.

It becomes obvious that the variety of factors that influence the choice of the principal direction requires the adoption of balanced and reasonable design decisions, which largely determine the future investment and operating costs, as well as the economic efficiency of the projected railway.

The works of many scientists are devoted to solving this complex multi-variant and multi-criteria problem, among which we should note the works by A.V. Gorinov, I.V. Turbin, S.M. Goncharuk, A.V. Gavrilenkov, V. A. Podverbny, Yu.A. Bykov and others.

2. Materials and Methods

This article discusses the main provisions of the methodology for multi-criteria assessment of the competitiveness of the direction options of the designed railways, which includes four main stages:

1. Formation of the initial set of alternatives of the direction options:
   \[ x = \{x_1, x_2, ..., x_m\} \]  

2. Formation of an acceptable set of alternatives of direction options:
   \[ y = \{y_1, y_2, ..., y_n\}, \ n < m. \]  

3. Formation of an effective set of alternative direction options:
   \[ z = \{z_1, z_2, ..., z_k\}, \ k < n. \]  

4. Determination by enlarged indicators of economic efficiency of design solutions for recommended options for further development of the direction from the set \( z \).

The diagram shows the sequence of evaluating the competitiveness of options for the directions of the projected railway at the pre-project stage.

**Figure 1.** Scheme of sequential assessment of the competitiveness of options for the directions of the projected railway at the pre-project stage.

At the first stage of the method, graph theory methods are used to form the initial set of alternative direction options. They allow us to consider all possible direction options connecting strong points and fixed points that are nodes of the graph.
For the first time, the use of graph theory methods for forming a set of railway direction options was proposed by A.V. Gavrilenkov [1] and further developed in the works of Yu.A. Bykov.

It is known from graph theory that a subgraph that connects all nodes of graphs and does not contain closed contours is called a "complete tree". The number of such trees or the number of possible directions is calculated using the adjacency matrix determinant \( d = |a_{ij}| \), \( a_{ij} \) - the number of edges with nodes \( i \) and \( j \) as endpoints, taken with a minus sign; \( a_{ii} \) - the number of edges adjacent to node \( i \) (\( i = j = 1, \ldots \)).

The described approach to the formation of the initial set of options for the direction of the projected railway allows us to consider all possible options, the assessment of the competitiveness of which is considered at the next stage of the methodology.

The second stage of the methodology is devoted to evaluating the competitiveness of the direction options from the set \( x = \{x_1, x_2, \ldots, x_m\} \) obtained at the first stage.

The method assumes the use of a modified SWOT analysis algorithm [2].

SWOT analysis allows both quantitative and qualitative assessment of the internal and external environment of the research object, while the internal environment is considered in terms of the strengths (S) and weaknesses (W) of the research object, and the external environment - in terms of the emergence of opportunities (O) and threats (T) for it [3].

A significant feature of the SWOT analysis method is the ability for the decision-maker to form well-known, but disparate and in some cases unsystematic ideas about the research object and its environment in the form of a logically consistent scheme of interaction of forces, weaknesses, opportunities and threats.

The authors of the article confirmed the possibility of using SWOT analysis to assess the competitiveness of options for the direction of projected railways, taking into account a large number of factors of the external environment (socio-economic, natural, environmental, etc.) and the internal environment (technical factors).

Methodological approaches to conducting a modified SWOT analysis of project decisions made at the initial (pre-project) stage by the example of choosing a direction option are considered in the work of the authors [4].

At this stage, a comprehensive analysis of internal and external factors that influence the choice of the direction of the projected railway allows us to "filter out" clearly non-competitive options and "narrow" the IMA to an acceptable set of options \( y = \{y_1, y_2, \ldots, y_n\} \), \( n < m \).

The third stage of the method involves a multi-criteria assessment of the considered alternatives from the set of acceptable ones using the ideal point method.

As is known, the "ideal" method in this case is a conditional variant that has extreme (minimum or maximum) values for all the considered criteria.

The result of using the method is the definition of a generalized indicator in the accepted criteria space:

\[
g = \sqrt{c_1 r_1^2 + c_2 r_2^2 + \cdots + c_j r_j^2} \quad (4)
\]

where \( r_1, r_2, \ldots, r_j \) - normalized partial criteria; \( c_1, c_2, \ldots, c_j \) - weight coefficients; \( \sum_{j=1}^{J} c_j = 1, \ c_j > 0 \). \quad (5)

The closer the option is to the "ideal" (less than \( g \)), the better it is.

The use of the ideal point method for multi-criteria evaluation of variants of projected railways is considered in the work of the authors [5].

The result of the third stage of the method is the formation of an effective set of alternatives options for the direction \( z = \{z_1, z_2, \ldots, z_k\} \), \( k < n \).

The fourth and final stage of the methodology under consideration offers a determination of the economic efficiency of options recommended for further, more detailed design based on aggregated indicators (required investments, income).
3. Conclusion
The proposed method multivariate and multicriteria evaluation of design decisions at the direction of the projected railway allows decision makers at each stage to fully assess the competitiveness of the options considered with the use of a large number of criteria (indicators), with both qualitative and quantitative evaluation, which significantly increases the objectivity of design decisions. The developed methodology can also be used to assess the competitiveness of options for passing international transport corridors through the territory of the Russian Federation.

4. References
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