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FUZZY-LOGIC EXPERT SYSTEM TO ESTIMATE THE RISKS OF HIGH-SPEED RAILWAYS PROJECTS

Complex infrastructure projects like high-speed rail line, require a deep and comprehensive risk analysis. In the process of implementation, there are many uncertainties, changes and degree of impact of risks on the project. The article from the point of view of methodology project management the approach to risk analysis project high speed railway Moscow – Kazan, based on the methods of fuzzy logic. Developed and proposed Simulink model of risk assessment given the dynamics of development of the project.

INTRODUCTION

For large-scale and multifaceted projects, such as high-speed railway (HSR), at the initial stage there are many uncertainties, inaccuracies, fuzzy conditions. Therefore, the decision about implementation should be based on a deep analysis of possible negative situations and methods to reduce their negative impact on the project.

The implementation of such infrastructure projects as high-speed rail (hereinafter – the Project), involves the attraction of private investment through the mechanism of public-private partnership (PPP). Federal Law Russian Federation No. 115 "On concession agreements" determines the order of application of such a mechanism in the form of concession. Risks arise at all stages of formation and implementation of the concession agreement, cannot always be foreseen and taken into account, and in some cases, have a high degree of uncertainty.

Currently, economic analysis, banking practice, expert systems, automatic control systems, when the task solution is impossible to obtain complete information or the definition of which is not sufficiently widely used methods of fuzzy and hybrid systems. Modern

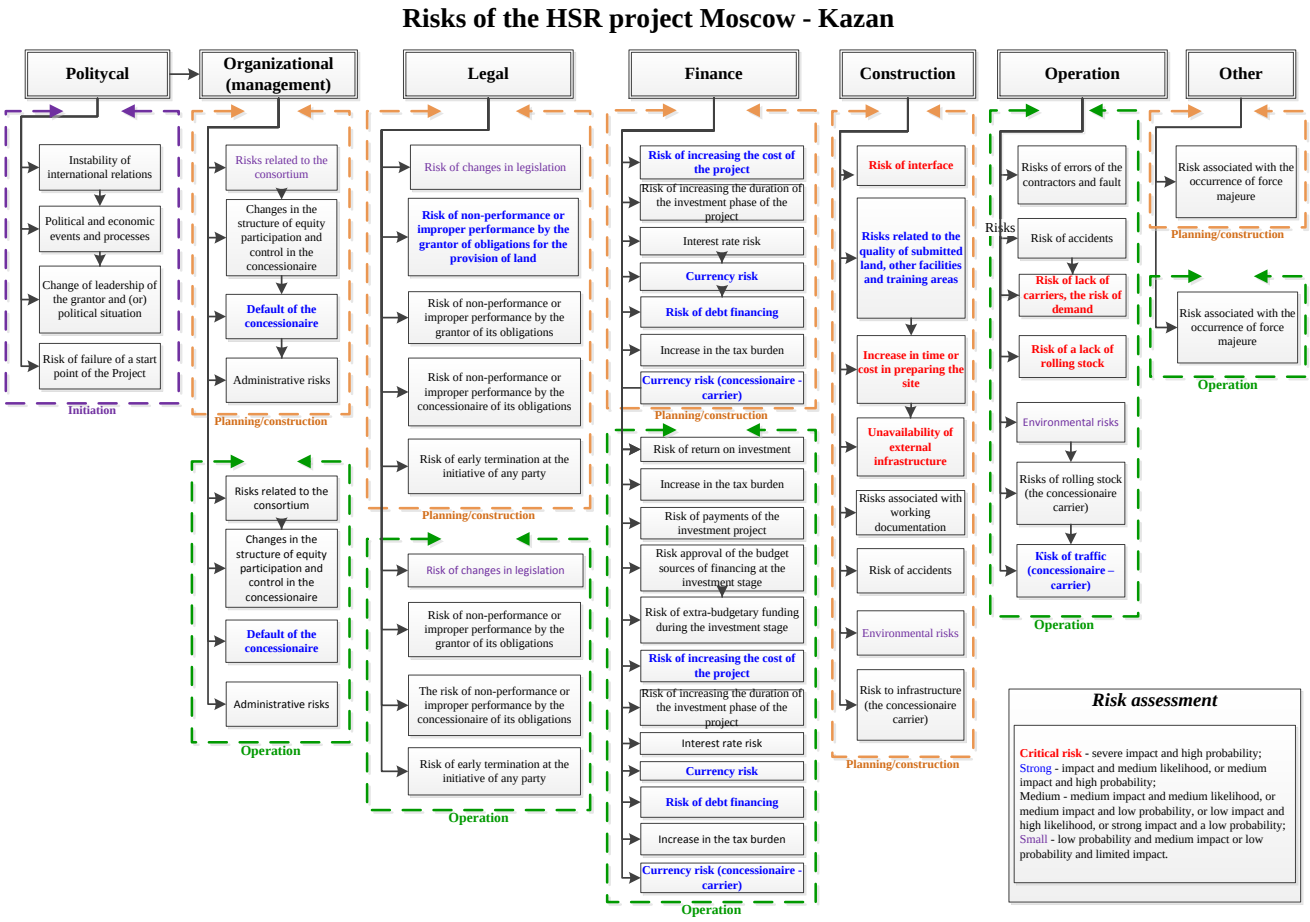

Fig. 1. *Hierarchical risks structure of the HSR project Moscow – Kazan*

advances in control theory and computer science provide an opportunity to significantly enhance the quality of decisions through the use of intelligent systems based on fuzzy logic methods.

1. ESTIMATE THE RISKS OF HIGH-SPEED RAILWAYS PROJECTS

The article discusses the construction of a model expert system for risk assessment of HSR projects with the use of a method based on fuzzy logic.

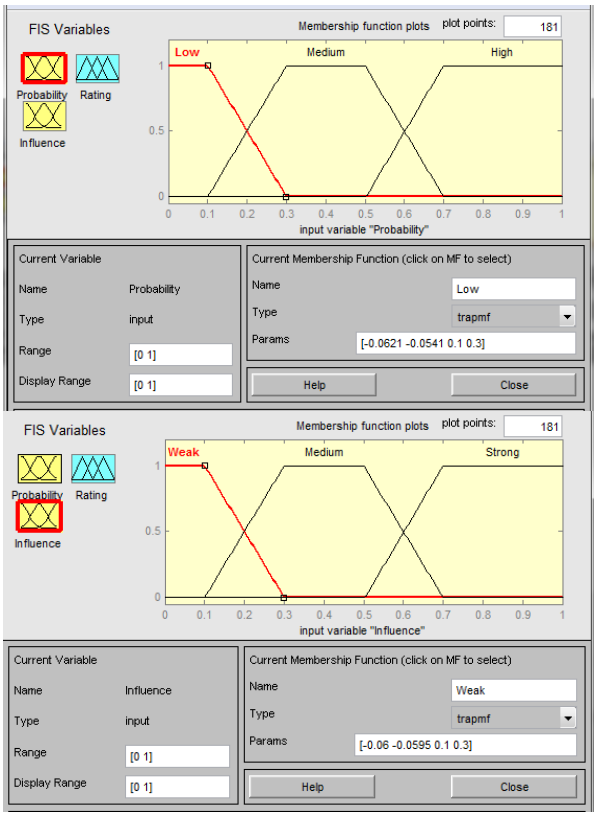

Fig. 2. *The membership functions of the input factors*

The project management methodology [1,2] provides 4 risk management process:

1. Planning group:
   a) identification of risks;
   b) risk assessment.
2. The project group:
   a) development of anti-risk measures.
3. In the management group:
   a) risk management.

The purpose of risk identification is to identify potential risk events and their characteristics that, if they occur, can have a positive or negative effect on Project objectives.

As a result of risk identification must be received the risk register, based on which further risk assessment.

At the initial stage of the Project it is necessary to use a predesigned scheme of categorization of typical risks, which may take the form of a simple list of categories or be issued in the form of a hierarchical structure of risks [3]. The hierarchical structure of risks (RBS – Risk Breakdown Structure) is a hierarchically organized depiction of identified risks of the Project, grouped by category and subcategory that identifies the various areas and causes of potential risks.

RBS of the HSR project can be broken down into the following risk categories:

1. Political.
2. Organizational (management).
3. Construction.
4. Legal.
5. Financial.
6. Operating.
7. Other.

In addition, RBS is advisable to consider at different stages of a Project as it develops. The hierarchical structure of risks of the HSR project is presented in Fig. 1. There is added conditional time frame (subcategories) risk: initiation, planning and construction, operation.

At a deeper detail the hierarchical structure of risks should be agreed in time with the hierarchical structure of works (WBS – Work Breakdown Structure) and Project schedule.

The purpose of risk assessment is to assess and prioritize risks for further action. This process includes evaluating the likelihood of each risk and the corresponding consequences (degree of influence) for the purposes of the Project if the risk will take place.

In fuzzy logic model applied the Mamdani algorithm [4, 5], which involves the following steps.

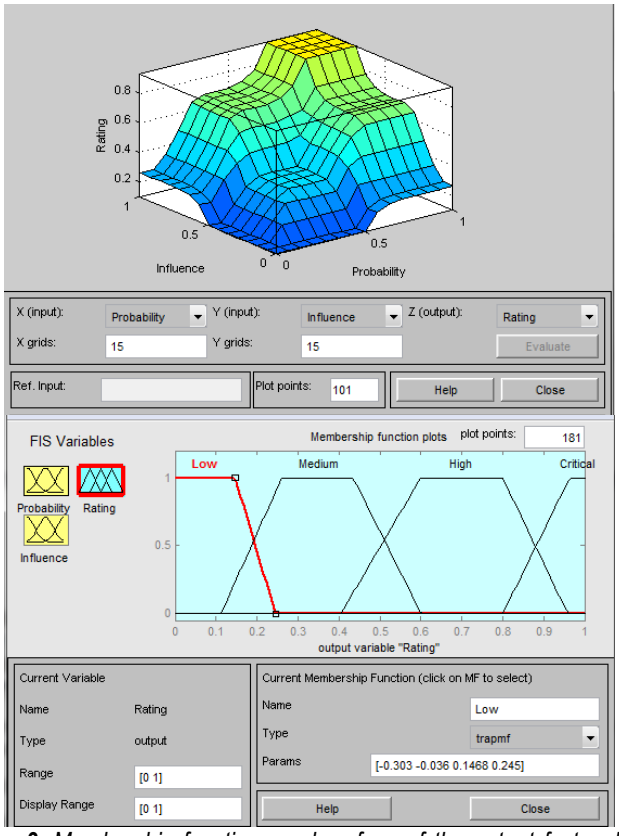

Fig. 3. *Membership functions and surface of the output factor depending on the input factors*

In the first step are selected factors, which are presented as fuzzy values. Next is the fuzzification, i.e., constructed of the characteristic function or membership function of input parameters (factors) and output parameters (risk assessment) of the Project and specified the possible ranges of their changes.

In the second step, on the basis of existing ideas about the nature of influence factors on the assessment of risk should be formulated and described by rules that associate factors and risk assessment together.

In the third step, we construct a model based on fuzzy logic and is bringing the definition (defuzzification) when it is necessary to convert the fuzzy set of conclusions as to the exact number.

Consider the evaluation of some factors (risk). Choose as input two fuzzy values:

1. The probability of occurrence (further denote the probability) is assessed by a three-digit scale:
   - low;
   - medium;
   - high.
2. The degree of influence (hereinafter - the influence) are also measured at the three-digit scale:
   - weak;
   - medium;
   - strong.

As the output variable (risk assessment rating):

- critical risk (critical) - strong influence and high probability;
- high/strong risk (high) - strong influence and medium probability, or medium influence and high probability;
- medium risk (medium) - medium influence and medium probability, or medium influence and low probability, or weak influence and high probability, or strong influence and a low probability;
- small risk (small) low probability and medium influence or low probability and weak influence.

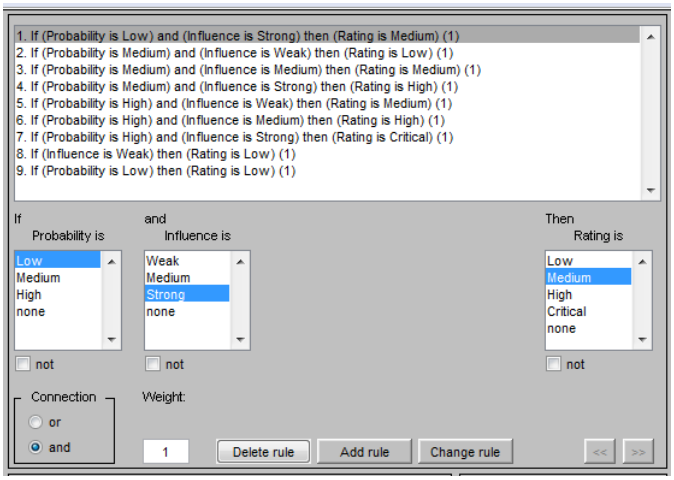

Fig. 4. *An example of the formation of fuzzy rules the relationship of the input and output factors*

The next stage is to select or specify a characteristic function (membership functions) for input and output parameters. The membership function may be triangular, trapezoidal, in the form of the Gauss function, sigmoid, and other species.

As the membership functions of each factor (risk) select the trapezoidal representation of fuzzy numbers (probability - probability and influence – influence). The range of variation of membership functions from 0 to 1 (Fig. 2). Output variable (risk assessment Fig.3) – Rating represented by 4 trapezoidal membership functions: low risk – Low; medium risk – Medium high risk – High; critical risk Critical. The range of variation of each membership function is defined from 0 to 1.

In the second step, it is necessary to describe the linguistic rules relating the input factors and output value – risk evaluation, for example:

If the probability is low and the influence is weak, then the risk is small;

If the probability is high and influence is medium, the risk is high;

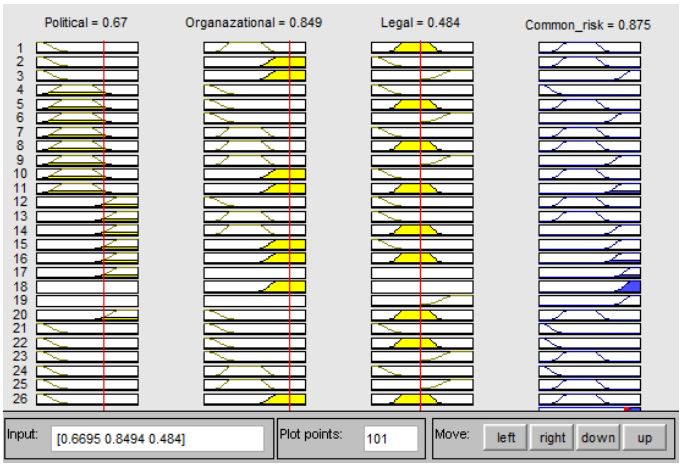

Fig. 6. *An example of the result of a comprehensive risk assessment*

In Fig. 4 provides a General list of rules for the fuzzy logic model with two inputs and one output.

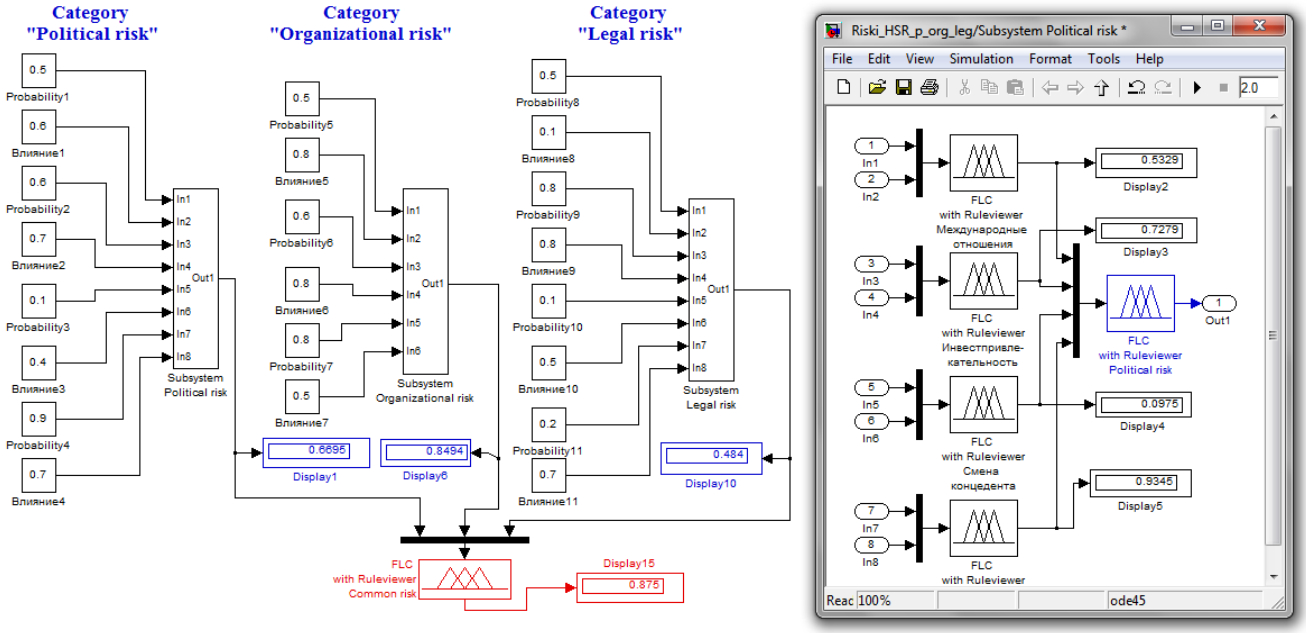

Fig. 5. *Fuzzy-logical model of risk assessment of the HSR project at the preparation stage to the decision on the conclusion of the concession agreement*

In the third step is bringing the fuzzy output into crisp numbers or defuzzification.

The model is designed for individual assessment of any risk and can be used in different risk management processes (in groups planning, implementation and control) and at different time intervals, and inputs a more sophisticated hierarchical risk model. However, risk analysis is a complex, multifactorial Project must consider, whenever possible, the whole range of existing and changing risks.

In identification, risk assessment at the stage of preparation for the decision on the conclusion of concession agreements need to consider three main categories of risk: political, organizational (management), legal. Other categories: financial, construction, operational, other need to be considered in subsequent phases.

To build complex fuzzy logical model in the framework of hierarchical structure of risks was developed Simulink model (Fig.5) using fuzzy logic controllers (FLC with Rulevieur). For example, at the input of the controller, categories of political risk (Political FLC with Rulevieur) 4 fuzzy variables – risk (international relations, investment attractiveness, risk of change of the grantor, the failure of the Project launch date).

Fuzzy inference in each risk category can be given to the clarity and converted to a General (complex) risk assessment for the Project. Clear the logical output of each controller is reflected in the units Display.

In Fig. 6 shows an example of evaluation of risk categories and the overall risk of the Project at the stage of preparation for the decision on the conclusion of concession agreements, in Fig. 7 – surface of fuzzy conclusions of the risk categories.

On the basis of RBS and using the described approach consistent build fuzzy logic risk assessment model was developed Simulink model of risk assessment of the HSR project (Fig. 8). The input of each controller serves two fuzzy values: probability and influence. The degree of uncertainty of each of them can be changed and set by an expert way. In the result of the simulation yields a risk assessment for each category. On the basis of the situation prevailing at the time of the assessment, it is possible to give more or less importance of the corresponding category, receiving an overall risk assessment of the Project.

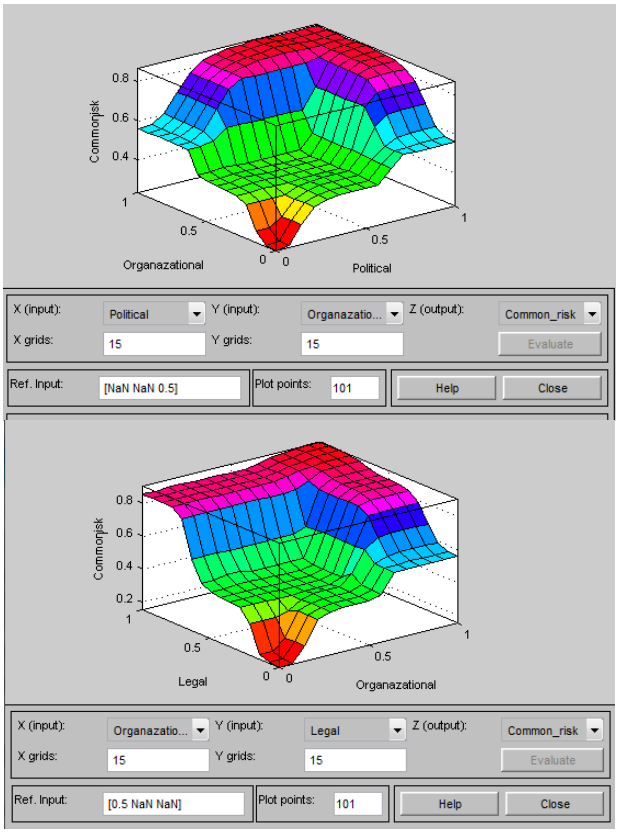

Fig. 7. *The surface of fuzzy conclusions of the risk categories*

CONCLUSION

Developed an expert fuzzy-logic model allows you to:

1. To produce a risk assessment (including economic) at all stages of a Project, in dynamics of its development, to track changes in the structure of risk, upon completion of the works in accordance with a hierarchical structure.
2. To determine the most critical areas of the Project.

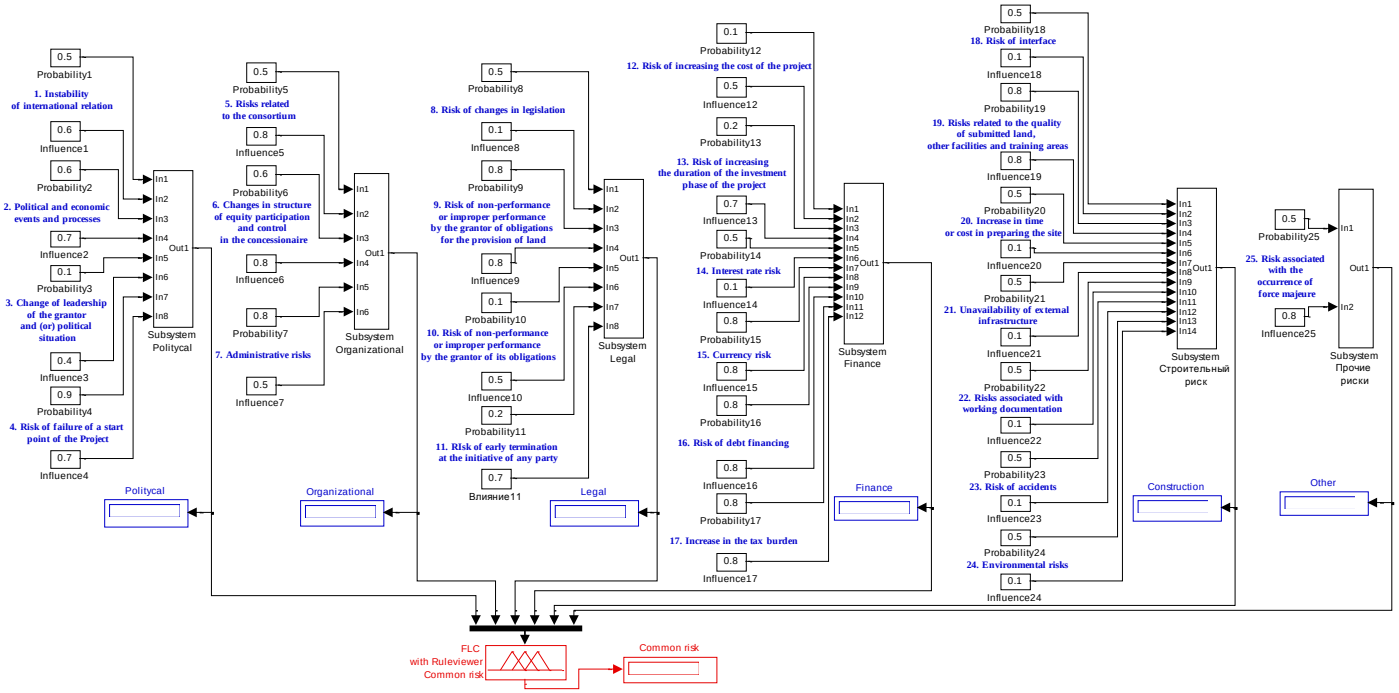

Fig. 8. *Fuzzy logic Simulink model of risk assessment of the HSR project*

3. Form a plan of responses to risks and to adjust it in the Project development process.

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System ekspercki do oceny ryzyka projektów kolei dużych prędkości

Artykuł przedstawia aspekty zarządzania projektami metodologii podejścia do analizy ryzyka projektu szybkiej kolei Moskwa - Kazań, oparty o metody logiki rozmytej. Opracowano i zaproponowano model oceny ryzyka w programie Simulink, z uwagi na dynamikę rozwoju projektu.

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