

# RISK LEVEL EVALUATION OF CONSTRUCTION INVESTMENTS PROJECTS

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Management of investment risk is a usual practice of any investment project or business. The estimation of risk must be carried out at various project stages. In practice it is impossible to avoid not exhaustive and inaccurate information, therefore, unfavourable risky situations occur, the consequences of which can be very damaging to the project or business. Due to close cooperation of the participants of the project the risk occurring in one stage of the project can transfer to other stages and one type of risk can change into another one. This means that chain reaction is characteristic to the risk and it decreases efficiency and safety of any project or business. Various types of risk can be caused by different factors. Classification of risk is determined by efficiency of risk management organisation. Risk classification is understood as risk allotment according to certain features into concrete groups for reaching the set objectives. Conceptually reasoned risk classification allows defining the role of each risk in the total system of all risks. This paper presents methods of multiattribute comparative analysis (CLARA and SAW methods) of variants of investment classified risks in construction. A practical case of illustrating the methods work is presented.

**Keywords:** *investment, project, risk, multi-attribute analysis*

## 1. Introduction

Decision-making problems in construction management often involve a complex decision-making process in which multiple requirements and conditions have to be taken into consideration simultaneously. Thus quantitative and qualitative assessments are often required to deal with uncertainty, subjective and imprecise data [1]. Organizational and technological complexity of construction projects generates enormous risks. Investment risk managing theory allows planning investment problems [2, 3]. Managing the risk of investments means presence of an effective control for all procedures in any phase of the project, when varying factors are taking place, which influence the realization of the project. In most cases, any investment project possesses several parameters of efficiency. Conditions of investor works continuously change assessment. For this reason rules of investment projects quality at this moment can be based only on the investor's leadership politics. The principle of quality valuation is based on the intuition and experience of the decision maker [4, 5, 6].

In practical use task of getting expert knowledge in many cases can be formulated like task of classification, because expert intelligence is to sort objects (alternatives, state of object) through classes of decision. Elements formatting some whole to be classified may have different origin. It can be different physical objects, cases of choice or condition of some object [7, 8, 9, etc.]. In recent years, multi-criteria evaluation methods have been widely used in solving both theoretical and practical problems. Actually, these methods are universal. They allow us quantitatively evaluate any complicated object described by a set of criteria. Another advantage of these methods is their ability to combine both maximizing and minimizing attributes expressed in various dimensions into one integrated criterion. The maximizing attributes imply that, if their values are growing, the situation is getting better, while for minimizing attributes this means a worsening situation [1].

A role of a risk valuation during decision-making becomes particularly essential [4, 5, 7, 10, 11, 12]. Different methods of multi-purpose choice of effective resource-saving investment are applied to select alternative, from the certain set of possible variants. For the majority of the problems solutions (LINMAP, TOPSIS, SAW, ZAPROS (ЗАПРОС), ORKCLASS (ОРКЛАСС), PARK (ПАРК), СИКЛ (ЦИКЛ), etc. [3,4, 12, 13] the qualitative or quantitative information is used. However, in praxis there are problems for which description the ordinal (serial) information or the information of both characters is necessary at the same time. Practical problems of the building investment project are solved at presence or absence of data on the importance of efficiency parameters.

Various methods for such problems solution are known [1, 2, 11, 12, 14, 15, 16, 17]. Multi-attribute decision-making methods have different characteristics [9, 10, 18]. In this article, we present CLARA and SAW (Ustinovichius *et al.* 2006a; Ustinovichius *et al.* 2008b) methods to multi-attribute comparative analysis of investments risk alternatives in construction in the given work. The offered methods have been successfully applied for the building projects assessment.

## 2. Verbal Decision Methods for Classification of Alternatives

Describing the method of prescription of the object to a certain class of decision is complicated because of inverbality of the strategy expert uses. Anyway, these inverbal skills are effectively and promptly used, when expert solves task of classification in his sphere of knowledge. Classification is a very important aspect in decision making [3, 4, 6, 7, 12]. One of the tasks preparing base for classification is setting of numerous criteria (attributes), which are able to describe any object. Scale of all criteria is formed by setting finite set of possible values [3]. If in certain task scale of values of one or more criteria is infinite, it can be modified to finite by cutting it to finite set of intervals. Finally, on the base of expert knowledge must be organised classification of definite intervals and its components i.e. must be formulated rules according which any object can be prescribed to one of the predefined classes. Classified projects are described by assessing various efficiency criteria that could be both qualitatively and quantitatively expressed.

The problem may be formally represented in the following way:

1.  $G$  is the property satisfying the target criterion of the problem;
2.  $K = \{K_1, K_2, \dots, K_Q\}$  is a set of evaluating criteria of an object;
3.  $S_q = \{k_1^q, \dots, k_{w_q}^q\}$  for  $q=1, \dots, Q$  is a set of estimates based on the criterion  $K_q$ ,  $w_q$  is the number of graduation marks on the scale of the criterion  $K_q$ ; the scales are arranged in the order of distinctness of the property  $G$ .
4.  $Y=S_1 \times \dots \times S_Q$  is the state space of the objects to be classified. Every object is described by a number of estimates based on the criteria  $K_1, \dots, K_Q$ . In this way, a set of alternatives  $\{y_1, y_2, \dots, y_L\}$  is defined, where

$$L = |Y| = \prod_{q=1}^Q w_q \text{ is cardinality of a set } Y, \text{ (the number of alternatives).}$$

5.  $C = \{C_1, C_2, \dots, C_M\}$  is a set of classes to be obtained by breaking down the set  $Y^a$ , which should be arranged in the ascending order of distinctness of the property  $G$  (in the class  $C_{n+1}$  this property is more distinct, while in the class  $C_n$  it is less distinct).

6.  $Y^a \subseteq Y$  is a set of *admissible* real objects;

Since the estimates based on each criterion are ordered, then, the scale showing the order of classes  $S_q$  can be compared with the numerical scale  $B^q = \{1, 2, \dots, w_q\}$ , where  $b_i^q < b_j^q$ , if  $b_i^q$  is less preferable for a decision maker (DM), then  $b_j^q$ .

The information of the DM preferences determines the relationships of rigorous preference (or dominance)  $P^0$  in the set  $Y$ :

$$P^0 = \{(y_i, y_j) \in Y \times Y \mid \forall q \in K \ b_i^q \geq b_j^q \wedge \exists q^0 : b_i^{q^0} > b_j^{q^0}\}$$

implying that the alternative  $x \in Y$  is dominant over the alternative  $y \in Y$ .

On the other hand, it is known that the classes of solution are ordered for the DM. It means that any alternative belonging to the class  $n+1$  is more preferable for the DM than any alternative of the class  $n$ . This is shown by the following binary preference relationship in the set  $Y$ :

$$P^1 = \{(y_i, y_j) \in Y \times Y \mid y_i \in Y_k, y_j \in Y_l, k > l\}.$$

It can be assumed that none of the vector estimates in the set  $Y$ , dominating over the given one, should be referred to a less preferable class. This statement is known as the "hypothesis of distinctness". It can be formally expressed as follows:

$$(y_i, y_j) \in P^0 \Rightarrow (y_j, y_i) \notin P^1 \tag{1}$$

Definition. Breaking down a set of vector estimates  $Y$  into the  $M$  ordered classes is consistent if the condition (1) is *satisfied* for any  $y_i, y_j \in Y$ .

Based on the preferences of decision maker, it is *required* to construct a consistent representation of  $F: Y^a \rightarrow \{Y_l\}, l = 1, 2, \dots, M$ , such that

$$Y^a = \bigcup_{l=1}^M Y_l; Y_l \cap Y_k = \emptyset, \text{ where } k \neq l, Y_l \text{ is a set of the vector estimates from } Y, \text{ assigned to the class } C_l.$$

There are some most frequently used verbal ordinal classification methods. Let us consider several most commonly used methods in more detail.

**ORCLASS** [3, 12]. This method (Ordinal CLASSification) allows us to build a consistent classification, to check the information and to obtain general decision rules. The method relies on the notion of the most informative alternative, allowing a great number of other alternatives to be implicitly assigned to various classes. ORCLASS takes into account possibilities and limitations of the human information processing system.

*Method assessment:* The main disadvantage of the method is low effectiveness due to the great number of questions to DM needed for building a comprehensive classification.

**DIFCLASS** [3, 12]. This method was the first to use dynamic construction of chains covering  $Y$  space for selecting questions to DM. However, the area of DIFCLASS application is restricted to tasks with binary criteria scales and two decision classes.

**CYCLE** [7, 12]. CYCLE (Chain Interactive Classification) algorithm overcomes DIFCLASS restrictions, generalizing the idea of dynamic chain construction to the area of ordinal classification task with arbitrary criteria scales and any number of decision classes. The chain here means an ordered sequence of vectors  $\langle x_1, \dots, x_d \rangle$ , where  $(x_{i+1}, x_i) \in P$  and vectors  $x_{i+1}$  and  $x_i$  differ in one of the components.

*Method assessment:* As comparisons demonstrate, the idea of dynamic chain construction allows us to get an algorithm close to optimal by a minimum number of questions to DM necessary to build a complete classification. The application of ordinal classification demonstrates that problem formalization as well as introduction of classes and criteria structuring allows solution of classification problems by highly effective methods.

**CLARA** [3, 4, 6]. This method (CLAssification of Real Alternatives) is based on ORCLASS, but is designed to classify a given subset rather than a complete set of alternatives ( $Y$  space). Another common application of CLARA is classification of full set with large number of exclusions, i.e. alternatives with impossible combinations of estimations. In both cases CLARA demonstrates high effectiveness.

Nowadays, computer software can assist many management techniques like sensitivity analysis and improve the efficiency of the analyzing process. Computer simulation packages are thought to be more realistic than theoretical calculations. The method/program CLARA can be successfully applied to classification of investment projects when the decision classes and the criteria used are thoroughly revised.

### 3. Simple Additive Weighing (Saw) Method

*Stage 1.* Decision-making matrix's forming.

$$P = \begin{matrix} & x_1 & x_2 & \dots & x_n \\ \begin{matrix} a_1 \\ a_2 \\ \vdots \\ a_m \end{matrix} & \left[ \begin{matrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{matrix} \right] \end{matrix}, \tag{2}$$

Where:  $m$  – number of alternatives;  $n$  – number of attributes.

$$i = 1, \dots, m; j = 1, \dots, n.$$

We find the best values of each parameter according to the formula (3)

$$\begin{aligned} x_j^* &= \min_j x_{ij}, \text{ if preferable is minimum of } j^{\text{th}} \text{ attribute,} \\ x_j^* &= \max_j x_{ij}, \text{ if preferable is maximum of } j^{\text{th}} \text{ attribute.} \end{aligned} \tag{3}$$

*Stage 2.* Performing normalization of the decision making matrix. The normalization values of normalized decision making matrix  $\bar{P}$  are calculated according to the formula (4)

$$\bar{x}_{ij} = \frac{x_{ij}}{\max_j x_{ij}}, \text{ if preferable value of the } j^{\text{th}} \text{ attribute is maximum,} \tag{4}$$

$\bar{x}_{ij} = \frac{\min_j x_{ij}}{x_{ij}}$ , if preferable value of the  $j^{th}$  attribute is minimum.

**Stage 3.** Defining weighted normalized matrix  $\hat{P}$ . Values of the  $\hat{P}$  matrix are calculated multiplying values of  $\bar{P}$  matrix by corresponding weights of significances of each attribute:

$$\hat{P} = \begin{bmatrix} q_1 \bar{x}_{11} & q_2 \bar{x}_{12} & \dots & q_n \bar{x}_{1n} \\ q_1 \bar{x}_{21} & q_2 \bar{x}_{22} & \dots & q_n \bar{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ q_1 \bar{x}_{m1} & q_2 \bar{x}_{m2} & \dots & q_n \bar{x}_{mn} \end{bmatrix} \quad (5)$$

**Stage 4.** Defining efficiency criterion for each alternative:

$$K_i = \frac{1}{n} \sum_{j=1}^n \hat{x}_{ij}, \quad i = 1, \dots, m; \quad j = 1, \dots, n. \quad (6)$$

Optimum variant and ranks of the alternatives are established by size  $K_i$ .

$$K^* = \left\{ a_i \left| \max_i \sum_{j=1}^n q_j \bar{x}_{ij} \right. \right\}, \quad i = 1, \dots, m; \quad j = 1, \dots, n; \quad \sum_{j=1}^n q_j = 1. \quad (7)$$

After parameters are defined, it is necessary to estimate its weights. The expert method of pair comparison is applied to determine of attributes Saaty for this purpose [19].

It is known, that in a basis of human perception of surrounding reality, the decomposition and synthesis present. While studying any system, the person makes its decomposition to subsystems. Having revealed attitudes between subsystems makes its synthesis. Decomposition of a problem is made on the basis of the risk qualifier (presented in the form of Table 1). We make the synthesis by applying SAW method.

To determine a priority it is recommended to use an importance scale which was offered by Saaty [19]. The group valuation can be considered enough reliable only in the case, when opinions of interrogated experts are consentaneous. Therefore, investigating the information received from experts statistically, it is necessary to valuate a coordination of their opinions and to determine the information heterogeneity reasons [20].

#### 4. Case Study: Determination of the Most Suitable Alternative for Investments

Organizational and technological complexity of construction projects generates enormous risks. Investment risk managing theory allows planning investment problems. Managing the risk of investments means presence of an effective control for all procedures in any phase of the project, when varying factors are taking place, which influence the realization of the project. In most cases, any investment project possesses several parameters of efficiency. Conditions of investor works continuously change assessment. Investment projects' quality rules can be based only on the investor's leadership politics at this moment. The quality evaluation principle based on the intuition and experience of the decision maker. We present investments problem to the construction in this article.

Every construction project is unique and each has different risk allocation, capital requirements, management teams, construction methods etc. All these factors could affect project cost, and thus it is necessary to identify and analyse the risks associated with project budget and realization.

##### 4.1. Application of CLARA method to multi-attribute comparative analysis of investments risk alternatives

After a few iteration series expert (DM) can choose final decisions - Final class decisions (Fig 3). Detailed description of these groups is provided in the first hierarchy level. Further the classification of the possible investment project risks must be established taking into consideration all levels of their multi-purpose quality descriptions -second hierarchy level. During that quality of the received results must be checked as well.

Risk level might be established using the composed classificatory, but a lot of criteria must be compared. It is a very difficult task for any person (for expert too), besides it takes a lot of time. Therefore, it is possible to use computer program CLARA (classification of real alternatives). This method (program) allows evaluating constructional investment project according to accurately established classes with the respectful offered criteria for risk size evaluation.

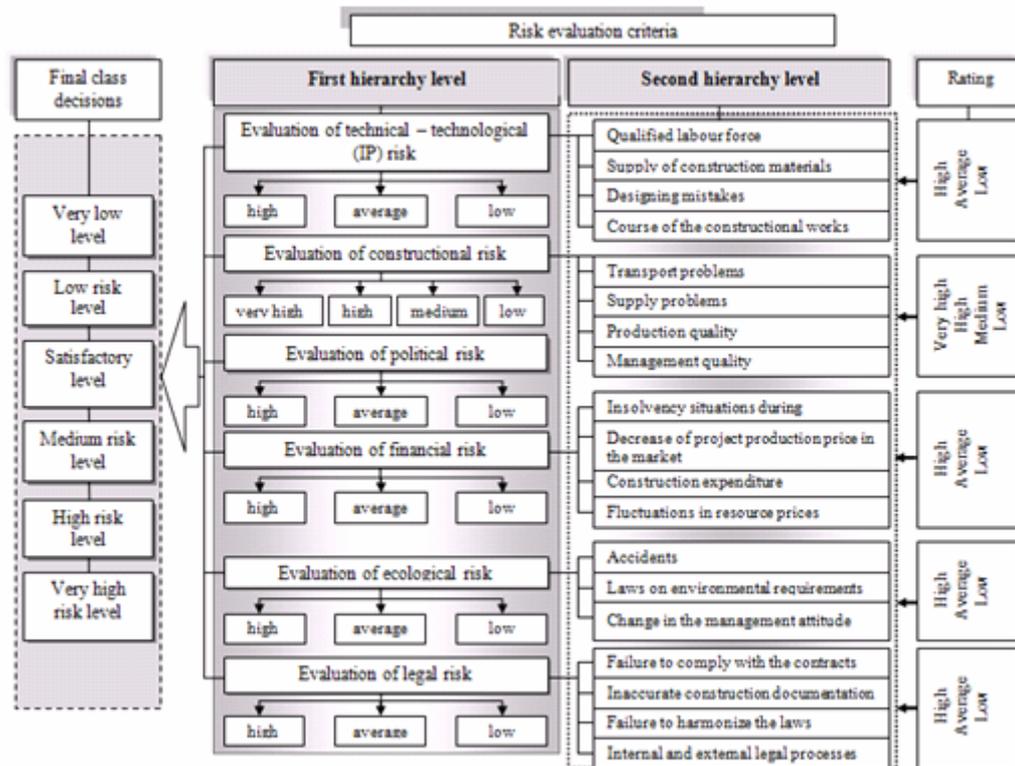


Figure 1. The classificatory of investment risks level evaluation

**Classifier establishment course.** Data input into the program.

**1 Stage** – For the second hierarchy level evaluation criteria are introduced:

- Criterion 1 – qualified labour force;
- Criterion 2 – supply of construction materials;
- Criterion 3 – designing mistakes;
- Criterion 4 – course of the constructional works.

Criteria evaluation classes:

- Class A – high;
- Class B – average;
- Class C – low.

Criteria 1-4 are chosen for evaluation of technical-technological risk. While analysing two projects (2 alternatives) the expert determines where the chosen labour force is qualified enough, where permanent continuous supply of materials will be ensured during the construction, what is the estimated course of works. After the project is analysed, it is determined if there are no mistakes in it. Other stages are input adequately to stage 1.

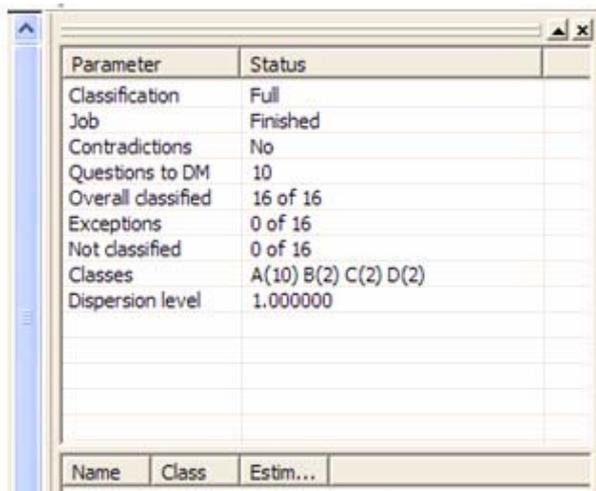
**Classification implementation in the program.** After introducing all the criteria that will be taken into consideration while evaluation 2 investment alternatives, the last stage is performed, i.e. the criteria are compared. The comparison is made in the following way: the program selects one evaluation of each criterion and composes their combinations. The expert assigns the available evaluation combination to the respectful class.

When the assigning is finished, a transfer is made to the next stage (by pushing the button “NEXT”). Another evaluation combination is provided. This is done up to a moment, until all the combinations are allotted to the respectful class.

During the work the expert might make a mistake or change his opinion, therefore, contradictions might appear in his answers.

In such case, the program shows a warning that contradictions have occurred and it will ask to confirm the new answer or to change it.

After the work is finished, the program saves all the data, performs analysis and shows the number of the given DM questions, the number of eliminated combinations. It also shows how many of evaluates combinations were allotted to classes A, B or C Evaluating of all second hierarchy level criteria are established in an analogous way.



Parameter	Status
Classification	Full
Job	Finished
Contradictions	No
Questions to DM	10
Overall classified	16 of 16
Exceptions	0 of 16
Not classified	0 of 16
Classes	A(10) B(2) C(2) D(2)
Dispersion level	1.000000

Figure 2. The data of program

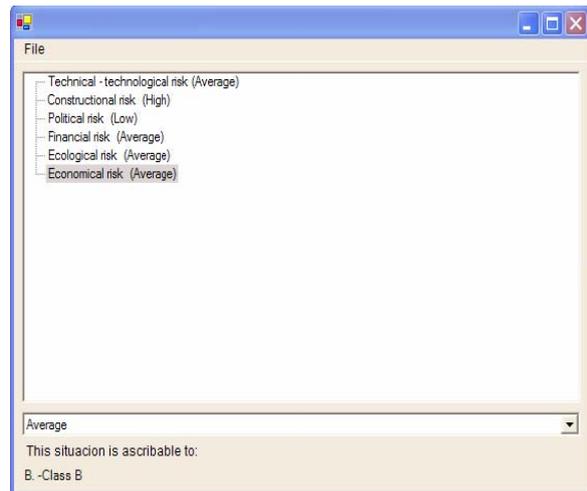


Figure 3. Data base (I hierarchy level)

**Final solving analysis.** The final analysis is performed according to the evaluations of the first hierarchy level. After the final analysis is performed, we get evaluation data, i.e. we establish risk levels (Fig. 3).

#### 4.2. Application of SAW method to multi-attribute comparative analysis of investments risk alternatives

An example of the implementation of the proposed method is included provided below and will provide the reader with a better understanding of the proposed methodology.

The investment company engaged in investments considered five possible alternatives of investments into construction of different objects. Projects have various volumes of investments and complexity of realization:

1. Very big and very complicated object – A the first alternative;
2. Two complicated objects – A the second alternative;
3. Three objects of average complexity – A the third alternative;
4. Six objects of average complexity – A the fourth alternative;
5. Eleven simple objects – A the fifth alternative.

The aim of the investor is to assess a risk level of projects and to choose one and the most effective project. After some iterations, as final classes of solutions for a valuation investment risk problem there were chosen (Table 1):

- *The Highest category of quality:* investors all obligations performance is practically assured, the credit line is opened for the investor, and the limit of crediting is established.
- *High category of quality:* the in-depth analysis of company activity and the investment project shows high probability of the borrower (investor) performance of all contracted obligations.
- *Satisfactory category of quality:* the investor can have some difficulties with performance of contracted obligations.
- *Low category of quality:* the investor can have the certain difficulties with performance of treaty obligations.
- *Unprofitable category of quality:* the investor is not capable to make repayment of the basic duty independently.

Realization of risk classification in possible investment projects on all levels of the multi-purpose quality description. Firstly, the risk level at the second level of hierarchy is defined. The valuation of parameters occurs on a scale of risk definition (from 0 up to 9). Further an orderliness of parameters and classification of risks on top-level hierarchies takes place. The final result - by the received quantitative results the most comprehensible project is defined. As a whole the analysis of the investment risk project by the SAW method is carried out in 3 stages. According to the calculations presented in the article, the most comprehensible from possible alternative amount has been chosen the 5th variant, i.e. eleven simple objects.

**Table 1.** The result table of experts interrogation - a matrix of decision-making

			$q$	$a_1$	$a_2$	$a_3$	$a_4$	$a_5$	
10	<b>Technological risk</b>	$x_1$	Mistakes of designing	0.0411	7	6	5	3	2
11		$x_2$	Lacks of technologies	0.0365	5	4	4	2	1
12		$x_3$	Erroneous calculation of capacity	0.0350	5	4	3	2	2
13		$x_4$	Mistakes of management	0.0328	7	4	5	2	1
14		$x_5$	Shortage of the qualified labour	0.0321	7	5	5	3	2
15		$x_6$	Failure of building materials delivery	0.0318	4	3	2	2	1
16		$x_7$	Non-observance by contractors (subcontractors) of terms	0.0314	5	4	3	2	1
17		$x_8$	Changes in prices of materials and energy carriers	0.0313	4	3	2	2	1
18		$x_9$	Increase in charges at a wages	0.0308	5	4	3	2	2
19		$x_{10}$	Increase in the prices of equipment	0.0306	3	2	2	1	1
	<b>Construction</b>								
21	<i>A-Period before termination of construction works</i>	$x_{11}$	Delays in construction	0.0305	7	6	4	2	2
22		$x_{12}$	Default from obligations of the supplier	0.0305	5	4	2	2	1
23		$x_{13}$	Stop of civil work on fault of the contractor's	0.0302	5	4	2	2	1
24		$x_{14}$	Risk of building materials shortage	0.0299	3	2	2	1	1
25		$x_{15}$	Availability of the contractor	0.0299	3	3	2	2	1
31	<i>B-Period after termination of construction works</i>	$x_{16}$	Quality of production	0.0291	3	4	5	6	6
32		$x_{17}$	Quality of management	0.0289	4	3	3	5	6
33		$x_{18}$	Realization of production	0.0289	5	4	3	5	6
34		$x_{19}$	Export – import	0.0288	6	5	4	6	7
35		$x_{20}$	Losses	0.0282	4	3	2	2	1
36		$x_{21}$	Transport	0.0281	4	3	3	2	3
37		$x_{22}$	Deliveries	0.0277	6	5	4	5	6
38	$x_{23}$	Incomparability of equipment	0.0277	6	5	3	2	1	
41	<b>Financial risk</b>	$x_{24}$	Inconstancy of economy in the country	0.0276	4	3	3	2	2
42		$x_{25}$	Inflation	0.0274	5	5	4	4	5
43		$x_{26}$	Situation payment delay in what or sphere of manufacture	0.0274	4	3	2	1	1
51	<b>Political risk</b>	$x_{27}$	Changes in tax system currency transactions	0.0268	4	4	2	2	2
52		$x_{28}$	Changes on sales and the customs control	0.0268	6	5	3	2	1
53		$x_{29}$	Changes of legislative system	0.0267	6	5	4	3	2
61	<b>Ecological risk</b>	$x_{30}$	Lacks of legislative system	0.0267	6	5	4	3	2
62		$x_{31}$	Failures	0.0263	5	4	3	4	5
63		$x_{32}$	Change of a position of the state on changes in the project	0.0249	5	4	3	2	1
71	<b>Legal risk</b>	$x_{33}$	Incompatibility of laws	0.0242	6	6	5	4	3
72		$x_{34}$	Discrepancies in the documentation	0.0234	5	4	3	2	1
			Optimisation direction for all attributes is minimum						
			$K_i$		<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
					<b>0.42</b>	<b>0.41</b>	<b>0.57</b>	<b>0.63</b>	<b>0.89</b>
			<b>Ranks of alternatives</b>		4	5	3	2	1

**Conclusions**

In conditions of market attitudes, an introduction of technical innovations and acceptance of effective decisions is necessary. Some courageous, not trivial decisions increase risk, however it does not mean, that it is necessary to avoid risk. It is necessary to be able to value a degree of risk and to operate it. The general conceptual approach for managing the investment risk in construction consists of following stages:

- a) revealing possible consequences of investment activity in a risky situation;
- b) development of measures which are not supposing, preventing or reducing damage from influence up to the end of not considered risky factors, unforeseen circumstances;
- c) such risk consideration system realization in business, where not only negative probable results can be neutralized or compensated, but also maximum chances of the high income are used.

Investment risk in construction can be evaluated efficiently enough using CLARA method. This method allows classifying all possible constructional investment projects presented by evaluations on the predefined criteria into several accurately defined classes reflecting the project risk level. The algorithm CLARA (Classification of Real Alternatives) is based on the dichotomy of the alternatives chains, beginning with the longest chain.

Criteria of the classificatory and the evaluations are introduced into verbal decision analysis support system CLARA, which allows performing criteria combination classification rather quickly. After all the above mentioned actions are performed, the person who wants to evaluate the investment risk, it is enough to introduce the respectful evaluations into the composed program data base and the program will provide the result – the risk level.

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