ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

Publisher
http://jssidoi.org/esc/home

MATHEMATICAL TOOLING OF ACCOUNTING NON-ECONOMIC CHARACTERISTICS DURING THE ASSESSING PROCESS OF INVESTMENT PROJECT EFFECTIVENESS *

Aidar S. Puryaev [1], Arslan A. Puryaev [2]

[1] Kazan Federal University, 18, Kremlyovskaya Street, Kazan, 420008, Russian Federation
[2] Moscow State University of Geodesy and Cartography, 4, Gorokhovsky pereulok, Moscow, 105064, Russian Federation

E-mails:[1] aidarp@mail.ru ; [2] ars.pur@mail.ru

Received 15 March 2019; accepted 10 October 2019; published 15 December 2019

Abstract. A search and analysis of sources (articles, conference materials, reviews) was conducted in the Web of Science Core Collection database from 1975 to March 2018 time period (57 sources) and in the RSCI database to March 2018 (48 sources) on the matter of using and recommendations of certain mathematical tooling in assessing the effectiveness of investment projects, taking into account non-economic characteristics. These 45 cases were identified in 41 sources of mathematical methods application in accounting for non-economic characteristics in the process of assessing the effectiveness of investment projects, their advantages and disadvantages. The recommendations on accounting for easily formalized non-economic indicators in evaluating project effectiveness were developed. Criteria have been established for classifying methods for taking into account non-economic characteristics as those that with a high degree of probability can do this in the value (money) scale. A mathematical tooling is proposed for taking into account difficultly formalized non-economic characteristics in the assessment.

Keywords: non-economic characteristics; assessment of efficiency; impact assessment; project appraisal; mathematical tooling

Reference to this paper should be made as follows: Puryaev, A.S., Puryaev, A.A. 2019. Mathematical tooling of accounting non-economic characteristics during the assessing process of investment project effectiveness. *Entrepreneurship and Sustainability Issues*, 7(2), 1114-1135. http://doi.org/10.9770/jesi.2019.7.2(23)

JEL Classifications: O22, O33, M11 https://www.aeaweb.org/econlit/jelCodes.php?view=jel

1. Introduction

The problem of evaluating the effectiveness of investment projects is of particular relevance in the aspect of considering non-economic characteristics (externalities). In foreign practice of project evaluation, this issue is

* *The reported study was funded by RFBR according to the research project № 18-010-00018.*

studied from the angle of project impact assessment on various activity areas, on the environment, on human health, and on the stable development of society. In Russian practice this issue is less studied. In the official methodological recommendations devoted to assessing the effectiveness of investment projects (Kosov, Livshic, & Shahnazarova, 2000),("Methodical recommendations for evaluating the effectiveness of investment projects," 2008),("Method of calculation of indicators and use of criteria of efficiency of the investment projects applying for receiving the state support at the expense of means of Investment fund of the Russian Federation," 2009), this issue is studied in the framework of extremely general recommendations of a qualitative nature. The issue of an investment project's impact on the outside environment in Russian practice is considered as a question of evaluating social efficiency, based mainly on the cost approach. Nevertheless, there are works which are considered as attempts of mathematical formalization of the impact of non-economic characteristics on the efficiency and feasibility of investment projects.

This work is devoted to the analysis of the existing mathematical tooling in the arsenal of accounting of non-economic indicators, parameters in the modern methodology of evaluating the effectiveness and feasibility of projects and the development of author recommendations for its improvement. The identified frequency of using one method or another allows us to group certain assessment tools together and identify trends for their further development in application.

In order to improve the methodology and mathematical tooling for accounting of non-economic characteristics (externalities) in the process of evaluating the effectiveness of investment projects, the author’s classification of their subdivision into easily and difficultly formalized project characteristics (indicators, parameters, externalities and consequences) was proposed.

2. Method of research problems

Searching for sources (articles, conference materials, etc.) on the subject matter of research in the Web of Science Core Collection database for the time period from 1975 to March 2018 and in the RSCI database to March 2018 using certain search phrases presented thus in Tables 1 and 2. Out of all the identified sources (57 from the Web of Science Core Collection database and 48 sources from the RSCI database), 41 sources were analyzed in which certain mathematical tools are used in assessing the feasibility and effectiveness of investment projects. The analysis of the identified mathematical tooling was conducted to determine the possibility of considering of non-economic characteristics in evaluating projects. Search queries and search results are presented in Table 1 and 2.

Table 1. Types of effective search phrases and the number of sources for research in the Web of Science Core Collection database

№№	English (Google Translator), Web of Science Core Collection	The number of potential sources for analysis (without considering inappropriate to the subject of research)
1	"social effective* evaluation"	1
2	non-econom* and "effectiven* evaluation"	1
3	"non$economic*" "investment project*"	1(2-1=1)
4	"non-economic external*"	1
5	"non-economic param*"	2(5-3=2)
6	"non-economic characterist*"	1(7-6=1)
7	"ecological efficiency evaluation"	2
8	"invest* project*" and "national econo*"	16(27-11=16)
9	"eco-oriented” and “invest* project*"	1
10	"invest* project*" and "global econo*"	1(9-8=1)
11	non$economic external*	2(15-13=2)
12	"invest* project*" and "world econo*"	4(7-3=4)

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

13	"government invest* project*" and "effectiven*"	1(2-1=1)
14	"public invest* project*" and "effectiven* evaluation"	1
15	"public invest* project*" and "effectiv*"	5(11-6=5)
16	"Large-Scale Projects*" and "effective* evaluation"	1
17	"Large-Scale Project*" and "effectiven* evaluation"	1
18	"Large-Scale Project*" and "efficiency*"	4(55-51=4)
19	"Project Appraisal" and "Impact Assess*"	11(19-8=11)
20	Total	57 (168-111=57)

Source: compiled by the authors

Table 2. Types of effective search phrases and the number of sources obtained for research in the RSCI database

№№	Russian, RSCI	The number of potential sources for analysis (without considering obviously inappropriate to the subject of research)
1	"оценка обществ* эффектив*"	16(30-14)
2	"оценка эколог* эффектив*"	6(59-53)
3	"оценка эффект*" & "инвест* проект*"& "крупномасшт*"	15(16-1)
4	"оценка эффект*" & "инвест* проект*" & "миров* уровн*"	7(17-10)
5	"оценка эффект*" & "инвест* проект*" & "народнохоз* уровн*"	1(2-1)
6	внеэкономические характеристики	3 (15-12)
7	Total	57 (168-111=57)

Source: compiled by the authors

3. Research: analysis of existed mathematical tooling in assessing the feasibility and efficiency of investment projects

The analysis of 41 identified sources of the research subject showed a wide range of methods used (mathematical tools) in evaluating the effectiveness of investment projects.

3.1. CBA method (cost-benefit analysis) or «benefit-cost» method of analysis

This method is used and recommended in 22 cases out of 45 (in 41 sources under research) (Kosov et al., 2000), ("Methodical recommendations for evaluating the effectiveness of investment projects," 2008), ("Method of calculation of indicators and use of criteria of efficiency of the investment projects applying for receiving the state support at the expense of means of Investment fund of the Russian Federation," 2009), (Kogan, 2013; Medvedev, 2015; Novikova, 2005; Orlova & Safin, 2011; Pavlov, 2002; Velikaya & Papyan, 2015; Zhevlatova, 2013; Eddelani et al., 2019; Costanza, 2006; Droj & Droj, 2015; Huging, Glensor, & Lah, 2014; Jones, Moura, & Domingos, 2014; Joseph, Gunton, & Rutherford, 2015; Korytarova & Hromadka, 2014; Korytarova & Papezikova, 2015; Noble, Gunn, & Martin, 2012; Petrova, 2016; Selle & Zimmermann, 2003; Serikov, 2013; Serikov, Korneeva, & Petrova, 2014). Mathematical tooling: common algebraic valuation method (of *CBA* and "*Cash flow*" methods).

This is an approach to assessing of benefits and losses caused by each of the alternative options of action (projects, for example), used to select one of the variations. Or, it is a methodology for analytical comparing of positive and negative consequences of using alternative options of solution, requiring the monetary expression.

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

We will consider this method in terms of evaluating projects of predominantly of global and national economic significance. The CBA method consists of the following steps (Andruckiy, 2009):

1. Project objectives definition;
2. Project identification and prioritization;
3. Project feasibility and option analysis;
4. Project economic impacts analysis;
5. Project investment analysis;
6. Project financial ratios analysis;
7. Multicriteria analysis;
8. Project risks and sensitivity analysis.

The CBA method is based on the "Cash flow" method, which reflects the essence of the CBA method and its one section, Project investment analysis. The application of this method is becoming increasingly problematic for evaluation and implementation of investment projects of global and national economic significance, as it requires an assessment of non-economic effects, for example, the impact on the environment and sustainable development, on the cultural traditions of society, the assessment of social consequences, a region security, etc. An important feature of this method is the conversion into the value scale of assessments of various indicators, parameters, reflecting both positive and negative consequences of project implementation. What is the way of doing it for particularly qualitative indicators? For example, the quality of the population's life, the stable development of the region, country, the security of the country, etc. Unfortunately, this method does not give a definite answer to this question. The CBA and the "Cash flow" methods are oriented towards an option of solution that provides more benefits than costs in the monetary form in the visible forecast period. And for large-scale investment projects, for infrastructure projects the benefits of a region and a country are defined as a cost estimate of the consequences in the form of a change in macroeconomic indicators – increasing of GDP and employment of population, increasing in investment in the economy, etc.

It becomes obvious that the mathematical tooling of given cost method (CBA, Cash flow) can be used for evaluation of those non-economic characteristics which can be converted into value form and taken into account in payment flows not to the disbenefit of the calculations accuracy of the resulting efficiency indicator.

3.2. Method of multi-criteria optimization based on the use of Monte Carlo method and data matching

This method is used to minimize the weights uncertainty on the decision making criteria used in the 1st case out of 45 (in 41 of the studied sources). It is in a multi-criteria assessment of the social efficiency of the building's power supply using renewable energy sources. Mathematical tooling: Monte Carlo method and data consistency method. The described mathematical tooling: (Monte Carlo method) is usually applied for solving the following tasks:

a) Defining of mathematical expectation of some random variable. For this, a set of random values of a given value is generated and its average is determined. A random variable is usually characterized by a certain probability distribution.
b) Modelling of traffic flow using the Nagel-Schreckenberg model. In this case, Monte Carlo method is used to add an element of randomness and to estimate the probability of speed change of a traffic flow (Woods, 2015).
In the analyzed work by Barbara Mendecka (Mendecka & Koziol, 2015), Monte Carlo method is used as a tool for solving a discrete multicriteria optimization problem on the stage of determining of weighting factor for each decision criterion. For being more precise, the uncertainty of the weighting factor of decision criteria using Monte Carlo simulation and the method of data matching is minimized. Since the weighting factor are set by experts, then the Monte Carlo method allows to reduce subjectivity (uncertainty) in this process.

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

The advantage of this method is that it takes into account the element of randomness of any complex assessment process, for example, traffic flow, efficiency of performance, impact of the consequences of realized project on the external environment, etc. But there is one disadvantage of this method. This is the need to generate independent random variables, which is quite a difficult task, and it requires the use of some functions of certain programming languages (R or Python). Also, Monte Carlo method should apply large data samples for calculations to ensure error convergence (Woods, 2015).

In solving the problem of non-economic characteristics accounting in the assessment of a project's effectiveness, the calculation of weighting factor may be intentionally missed. Because, firstly, when specifying restrictions and desirable levels for one or another characteristics, a decision maker sets the significance of one or another parameter, which "throws back" the necessity of establishing weight factors. Secondly, it is supposed to take into account ten or more indicators simultaneously, which levels the process of using weight factor. Therefore, the process of generating random variables to eliminate the process of uncertainty, the establishment of weight factor by Monte Carlo method in this problem is eliminated.

3.3. Method of assessing energy efficiency

This method is used in the eucalyptus production system. One case out of 45 (in 41 of the studied sources). Mathematical tools: energy balance calculation method.

The method of calculating the energy balance is carried out according to the formulas (Romanelli & Milan, 2010):

$$E_B = E_{OF} - E_{IF} \tag{1}$$

$$E_{ROI} = {}^{E_B}/_{E_{IF}} \tag{2}$$

where:
E_B – energy balance, MJ ha^{-1}; E_{IF} – energy input flow, MJ ha^{-1}; E_{OF} – energy output flow, MJ ha^{-1}; E_{ROI} – energy return on investment, MJ MJ^{-1}.

This mathematical tool is extremely simple and has similarities with the traditional economic evaluation of efficiency. Only here the author measures flows not in the form of cash flows, but in the form of energy flows. This model is of special interest as it uses alternative units of measure of project efficiency, namely, units of energy (MJ). It should be noted that this model has its limitations in use, because is not universal, but narrowly oriented (specific). Not all non-economic indicators can be measured by the flow of energy.

3.4. Methods of risk and uncertainty assessment

1. Scenario method (tree scenario) or theory of games with «nature» (criteria of decision choosing: rule of Hurwitz, rule of Wald, rule of Savage, rule of Laplace). It is used in 4 cases out of 45 (in 41 of the studied sources) (Noble et al., 2012),(Kibalov & Shibikin, 2017),(Kibalov, Glushhenko, & Goryachenko, 2015),(Epishkina, 2010).
The scenario method of evaluation and selection has essential value for conditions of radical uncertainty. According to this method, for solving the problem of choosing the optimal variant from the set of existing alternatives, a scoring matrix of the following form is used:

Table 3. Scoring matrix

Alternatives $x'_i \in X'$	Scenario $x''_j \in X''$				
	x''_1	…	x''_j	…	x''_m
x'_1	u_{11}	…	u_{1j}	…	u_{1m}
…	…	…	…	…	…
x'_i	u_{i1}	…	u_{ij}	…	u_{im}
…	…	…	…	…	…
x'_n	u_{n1}	…	u_{nj}	…	u_{nm}

Source: (Epishkina, 2010)

In this matrix: $x'_i \in X'$ – is *i* alternative from the sets of existing alternatives *X'*; $x''_j \in X''$ – is *j* scenario of alternative development from the sets of existing scenarios *X''*; u_{ij} – strategy interaction outcome (alternatives) $x'_i \in X'$ with scenario $x''_j \in X''$.
Based on the matrix of uncertain outcomes $\| u_{ij} \|$, the most preferable outcome by a given criterion is determined, for example, the criterion of the public effectiveness of alternatives (Epishkina, 2010). Each outcome must be quantified. This is realized through expert review. In the works mentioned above for expert evaluation there will be used computer-aided support for assessment technology developed at the Institute of Economy and Industrial Production Organization of the Siberian Branch of the Russian Academy of Sciences. In any case, for appropriate evaluation and selection of the optimal variant it is necessary to have quantitative values of all outcomes. This may be a 10-point scale, the ratings for which are put down by experts in this field.

In a situation of radical uncertainty when the scenarios of actualization of these scenarios are difficult to determine and they are assumed to be unknown, then certain decision rules are used to determine the most preferred (optimal) option (Epishkina, 2010; Kibalov et al., 2015; Kibalov & Shibikin, 2017):

- the rule (criteria) of Hurwitz (*Hu*) with parameter $\lambda \in [0,1]$, which is interpreted as measure of decision-maker (DM) . For each alternative value period λ is defined according to which it the best by Hurwitz rule. A special case of the Hurwitz criteria is the rule of "extreme optimism" when $\lambda = 0$.
- the rule (criteria) of Wald (*Wa*) is a special case of *Hu* criterion when $\lambda = 1$. This criterion gives opportunity to choose the option with the maximum guaranteed result under the most adverse circumstances.
- the rule (criteria) of Savage is interpreted as a rule of "minimax regret" with the help of which a strategy that minimizes maximum risk is chosen.
- the rule (criteria) of Laplace is interpreted as a rule of "insufficient reason". In this case, when nothing is known about the implementation possibility of environmental scenarios, it is assumed that the scenarios are of the same probability (without sufficient grounds for this).

It is recommended to use the criteria of Wald and Savage as the optimal values give certain information about alternatives (guaranteed result and guaranteed regret). According to the Laplace's criterion, there is no convincing interpretation, since all scenarios are assumed to be equally probable. Therefore, this criterion is less preferable. It

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

is also recommended to calculate the range of values of the λ parameter for which the selected project is optimal according to Hurwitz and to compare this range with acceptable levels of risk for the DM.

The scenario method is designed to solve poorly structured or unstructured (qualitative) problems. This method does not allow to quantify the impact of each non-economic indicator on the feasibility of the project (efficiency). But it can definitely eliminate or reduce the uncertainty of the project's impact on the surrounding areas of activity and rank them among the available alternatives with a certain degree of probability.

2. Risk adjustment in the discount rate (Gert, Suprunchik, Nemova, & Kuz'mina, 2009). Used in the 1 case out of 45 (in 41 of the studied sources). In principle this tooling is often used to assess the riskiness of a project being implemented. The investor or DM deliberately lays an overestimated value of the discount rate (R) in case of unexpected circumstances when calculating the *NPV* of the project. Exceeding of IRR indicator of a project over R in this case will encourage the investor to invest and implement the project with a high degree of probability. The risk is taken into account, but there is no slightest possibility to consider the influence of the remaining non-economic characteristics directly on the resulting indicator of the project feasibility (efficiency). This method is limited in use though it considers only one non-economic characteristic (riskiness) quantitatively, regardless of the nature of its occurrence.

3. Risk assessment matrix method (Mironyuk, 2015; Noble et al., 2012; Platon, Frone, & Constantinescu, 2014). It is applied and recommended in 3 cases out of 45 (in 41 of the studied sources). Risk assessment matrices are presented in two types. The first type is a matrix of qualitative description (in the form of a table), which consists of the following columns: risk category, description of risk, consequences of risk and methods for risk reduction. It allows to identify the risk and qualitatively assess its effects and exercise its control. The second type is a matrix of quantitative estimates in the form of points. Each score assigns its context and each cell has its own color. For example (Platon et al., 2014):

- Risk is not significant: <0,75 Colour code: white (no color);
- Risk is significant: 0,75-1,5 Colour code: yellow;
- Risk is important: 1,6-2,25 Colour code: red.

This matrix allows you to quantify the risk and implement its gradation.
The second type of matrix is preferred for accounting of non-economic characteristics as a risk indicator in the effectiveness evaluation. At the same time, it is clear that this indicator cannot be taken into account in the value form in the flow of payments.

The same can be said about the risks described in work (Mironyuk, 2015). This paper discusses the components of the geological environment that may adversely affect ecosystems and engineering structures or cause their destruction (geohazard). Initially, geohazards are detected, then they are ranked and their priority is set. As a result, a geohazard registry is developed using various qualitative and semi-quantitative methods: HAZID (hazard identification), AET (analysis of "event trees"), analogy method, etc. For further identification and mapping of geohazards more specific actions are used. As a result, it can be concluded that risk assessment matrices, qualitative description and identification of risks can be used at the preliminary stage of project selection in terms of risk or their quantitative evaluation in the form of points should be reduced to a normalized form for considering them when evaluating the project effectiveness according to a certain methodology.

3.5. Fuzzy (vague) sets methods

1. TOPSIS method in combination with linguistic neutrosophic numbers (LNN) (Liang, Zhao, & Wu, 2017). It is used when assessing investment risk in mining projects, 1 case out of 45 (in 41 of the sources studied). It is

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

essential to assess the risks of complex ongoing projects, when there is a high uncertainty in the impact of certain factors. This method allows to take into account a whole range of qualitative risk factors. Preliminary, these factors are presented in the form of linguistic neutrosophic numbers. Therefore, the initial information for decision making is presented with a certain degree of belonging to a particular linguistic variable term. At the same time, the DM cannot adequately assess the degree of importance of each risk factor directly. A weight model, based on the calculation of the maximum deviation from the ideal is used for taking into account the degree of importance of a risk factor. There is used Technique for Order of Preference by Similarity to Ideal Solution (*TOPSIS*). *TOPSIS* is the method of determining the sequence to determine the solution proximity to the ideal. The method was originally used to solve some ranking problems. *TOPSIS* is a technology developed by Hwang and Yoon (Hwang & Yoon, 1981) in 1981. The basic principle of *TOPSIS* is that the selected alternatives should have the smallest distance to the ideal solution and the maximum distance from the ideal-negative solution. In a fuzzy environment this method is called *FTOPSIS* (from the word Fuzzy). Fuzzy logic in the advanced method is used to eliminate the uncertainty of the human factor.

This technique allows to prioritize and rank risk factors in conditions of high uncertainty in the process of implementation of an investment project and thus develop weighting factors for these factors. This is essential, specific (narrowly oriented) and adequate to reality in the process of evaluating the effectiveness of investment projects.

2. AHP- fuzzy comprehensive evaluation method. This method is used to select a building agent, 1 case out of 45 (in 41 studied sources) (Hu, Zhong, Wang, & Wu, 2016). In this paper we study the problem of choosing a building agent in order to carry out government regulation, to optimize contracts and moral hazard more effectively. For achieving this aim a combination of the AHP method and the fuzzy complex estimation method is used. This approach is of particular interest in performance evaluating in the conditions of high uncertainty.

The analytic hierarchy process (*AHP*) method was put forward by T.L.Saaty, a U.S. operational research expert. The essence of this method lies in the pair comparison of several alternatives (for example, investment projects) according to several criteria (evaluation parameters). The advantages of the method lies in the fact that it allows to transfer various parameters of a physical entity into a single normalized scale and then choose the one that satisfies the DM. The method of pair comparisons allows to reduce the subjectivity in establishing weight coefficients according to certain criteria as there is set a specified rating scale. Thus, it is possible to obtain a quantitative assessment of the criterion for each alternative and to choose the best one using a predetermined method or a generalizing method. In work (Hu et al., 2016) for reducing uncertainty in the selection process and complex assessment, a fuzzy mathematical model is created: multipliers are determined, a set of estimated results and the membership matrix R are set. As a result, the construction of a single fuzzy complex assessment matrix allows to adjust the weights of the primary assessment factors and choose a solution option in more adequate reality conditions. This method is adequate, real and deserves to be used in the problem of taking into account non-economic characteristics when evaluating the effectiveness of projects.

3. TFIEOWA operator's method for evaluating investment risk of building industry projects, 1 case out of 45 (in 41 studied sources) (Xu, Yang, & Hao, 2017). In this article, the authors study the problem of decision-making with several attributes to assess the risk of an investment project. The mood of investors is represented as a fuzzy set with a triangular fuzzy information. The *TFIEOWA* operator is the development of the authors of the article above and stands for triangular fuzzy induced Einstein operator with weighted averaging. This operator gives opportunity to reduce uncertainty effectively in assessing the risk of an investment project based on investor mood. The work actualizes the complexity of risk accounting problem in the evaluation of investment projects, actualizes the application of fuzzy sets, the creation of a special operator based on them to take into account the subjective opinion and mood of the investor and this is the advantage of the method.

4. Efficiency criteria in the scales of fuzzy sets theory (in the form of linguistic variables). This method is used in assessing the effectiveness of a large-scale investment project (project for the reconstruction of the Trans-Siberian Railway), 1 case out of 45 (in 41 sources studied (Kibalov et al., 2015). The two-level investment decision making model proposed by the authors consists of strategic and tactical levels. At the first level, the authors eliminate the first layer of fundamental uncertainty using the model of strategic investor games with "nature". In this case a model of the Russian economy is meant, which is defined in the form of an optimization intersectoral interregional model – railway transport (*OIIM-RT*), which was developed at the Institute of Economics and Industrial Production Organization of the Siberian Branch of the Russian Academy of Sciences. At the second tactical level, the parameters and criteria of effectiveness are formulated in terms of fuzzy sets for accounting uncertainty. For this purpose, we use linguistic variables with their term-sets. Each value of a term set (term) is determined by the evaluated parameter. Thus, there are set limits and (or) desirable levels for a parameter (an indicator that has numeric value) in the form of fuzzy numbers. A fuzzy number consists of two numbers. The first number is the value of the variable base, and the second is the membership function corresponding to a specific value (takes a value from 0 to 1). Each estimated investment project for a given parameter, using a triangular function of a fuzzy set, will have at least two estimates. This is more consistent with the real situation of choice and is an advantage of the technique.

3.6. Methods of the aggregation theory (generalization)

1. Desirability function method (Harrington, 1965; A. S. Puryaev, 2009; Aidar S. Puryaev, 2015). This method is applied in 3 cases out of 45 (in 41 studied sources). The use of the Harrington desirability function allows us to convert the individual parameters of the effectiveness evaluation, different in their physical nature and dimension, into a single dimensionless scale of assessment and then transfer into a single generalized criterion. Thus, it gives opportunity to take into account any non-economic characteristics in the assessment. It would be mentioned that one need to know their quantitative estimates, as well as the limitations (or desired levels) of the decision maker on these characteristics for making such an analysis. The decision maker (investor, customer) should set boundaries acceptable for him (upper, lower, or upper and lower) and then carry out the evaluation of the project. Advantage of the method is the following: the method allows to get away from the purely cost method; the task of evaluating the effectiveness becomes the task of finding the optimum for the whole complex of parameters (characteristics), including valuable. Minor drawback: the use of a sophisticated method of transferring the value of the estimated parameter Y into the Harrington scale of desirability d by applying an intermediate transform to a scale Y'.

The numerical preference system presented in Table 4 is the dimensionless desirability scale developed by E.S. Harrington (Harrington, 1965). The value of this scale have an interval from 0 to 1 and are denoted by d (from fr. *desirable*). The value of the i private optimization parameter, transferred into a dimensionless scale of desirability, denoted by d_i is called the desirability partial, where is the current parameter number; n is the number of private parameters. The value $d_i = 0$ corresponds to an absolutely unacceptable level of the i characteristic (optimization parameter). The value of $d_i = 1$ – the best value of the i parameter.

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

Table 4. Scale of Desirability by E.S. Harrington

Empirical system of preferences (desirability)	Numerical system of preferences (system of psychological parameters)
Very good	1,00 - 0,80
Good	0,80 - 0,63
Acceptable	0,63 - 0,37
Poor	0,37 - 0,20
Very poor	0,20 - 0,00

Source: (Harrington, 1965)

The desirability function corresponding to the E.S. Harrington desirability scale is as follows:

- for one-sided restriction:

$$d = e^{-e^{-y'}} \tag{3}$$

$$y_i' = \frac{y_{max} - y_i}{y_{max}} \tag{4}$$

$$y_i' = \frac{y_i - y_{min}}{y_{min}} \tag{5}$$

where y_{max}, y_{min} - the upper and lower limits of the one-sided restriction on the *i* private parameter; y'_i - the value of the *i* private parameter, transferred into a scale of desirability.

For defining y'_i It is recommended to use not a simplified method of rationing, presented in formulas (4) and (5), but a method of determining a first-degree polynomial to take into account the interests of decision makers:

$$y' = a_0 + a_1 \times y \tag{6}$$

where a_0, a_1 – coefficients of the equation of line.

The coefficients can be determined by setting two control points. The DM assigns value from the scale of desirability *d* to two value of the noneconomic characteristic *y* by his discretion and desire. These are the control points. Further, according to the formula obtained by conversion from the formula (3):

$$y' = -ln ln \frac{1}{d} \tag{7}$$

we determine the coded (normalized) value (y') of the corresponding control points. We determine the mechanism of transfer of *y* into y' using the two equations with two unknowns (a_0, a_1), (intermediate valuation mechanism).

- for two-sided limitation:

$$d = e^{-|y'|^n} \tag{8}$$

$$y' = \frac{2 \times y - (y_{max} + y_{min})}{y_{max} - y_{min}} \tag{9}$$

where y' is the coded value of the particular parameter *y*, i.e. its value on a conditional scale; *n* is an exponent.

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

After all the partial parameters (y_i) have been converted to their desirability (d_i) it is necessary to proceed with the construction of a generalized parameter of estimation (optimization), called by E.S. Harrington, a generalized function of desirability *D*. One of the successful ways of solving the problem of choosing the optimal variant is representation of the generalized desirability function as a geometric average of particular desirability:

$$D = \sqrt[n]{d_1 \times d_2 \times d_3 \times \cdots \times d_i \times \cdots \times d_n} \quad (10)$$

The generalized indicator of this type allows, firstly, to use the same scale of preference (see Table 4); secondly, "discard" the solution variant from the set of alternatives, if at least one of its particular parameters (non-economic characteristics) does not satisfy the strict requirements of the researcher (i.e., $d_i = 0$).

2. Method of rationing (Kharisova, Puryaev, & IOP, 2014). Applied in the 1 case out of 45 (in 41 of the studied sources). This method transfers different in physical essence non-economic parameters (indicators) to the function of desirability Harrington in the following way.

Non-economic indicators are transferred into a comparable form, i.e. in dimensionless units. It is proposed to determine the coefficient of significance (weight) of each indicator with the help of expert assessments. In addition to expert assessments, it is also possible to use the Fishburn formula for cases when indicators can be ranked only by their degree of importance: "not significant", "significant", etc .:

$$\alpha_i = \frac{(n-i+1)}{n \times (n+1)} \quad (11)$$

where α_i is the coefficient of significance of indicators of *i* category; *n* is the categories' number of innovative projects' efficiency indicators; *i* is the number of the particular category.

Then, estimates of each indicator are calculated according to the following formulas:

$$s_{ij} = \frac{SF_{ij}}{S_{maxij}} \quad (12)$$

where SF_{ij} – actual *i*-value for *j* project; S_{maxij}– maximum possible value of *i*-indicator for *j* project, if there is needed growth of *i*-indicator.

$$s_{ij} = \frac{S_{minij}}{SF_{ij}} \quad (13)$$

where SF_{ij}– actual *i*-value for *j* project; S_{minij} – minimum possible value of *i*-indicator for *j* project, if there is needed reduction of *i*-indicator.

Thus, the synthetic (final) indicator of the *j*-project is determined by the formula:

$$S_j = \sum_{i=1}^{n} \alpha_i \times s_{ij} \quad (14)$$

where S_j is synthetic indicator of the *j*-project; α_i - coefficient of significance (weighting) of *i*-category indicators; s_{ij} – estimates of *i*-indicator of the *j*-project.

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

The value of the synthetic indicator lie in the interval from 0 to 1. The closer the value of the synthetic indicator to 1, the more preferable the project, i.e. such a project is optimal. The advantage of the method is that for accounting of non-economic indicators the method of weighted average valuation is used. Disadvantage: the Fishburn formula greatly simplifies the determination of weighting coefficients, but the obtained value does not reflect the opinion of the decision maker.

Integral indicator method (Bersten & Egorova, 2007). Used in the 1 case out of 45 (in 41 of the studied sources). The essence of the method of assessing the environmental performance of the organizational structure of an industrial enterprise consists in transferring individual indicators into a normalized scale, determining the weighting (significance) coefficients of these normalized indicators (by an expert method) and determining the integral indicator within the group as a weighted average, and integrating the value of all groups in the enterprise as an average geometric. Below are the formulas for calculating (Bersten & Egorova, 2007):

$$K_i = \frac{I_i}{I} \tag{15}$$

K_i is a normalized value of the private *i*-indicator (parameter); I_i – value of private *i*-indicator (parameter); I – value of the overall indicator. величина общего показателя.

$$K_{gj} = \sum_{i=1}^{n} K_i \times k_{wi}\ , \tag{16}$$

K_{gj} is the integral indicator of the *j*-group of parameters; k_{wi} – weight coefficient of the private *i*-indicator (parameter); *n* – number of parameters in the group.

$$K_{ee} = \sqrt[m]{K_{g1} \times K_{g2} \times \cdots \times K_{gj} \times \cdots K_{gm}} \tag{17}$$

K_{ee} – integral indicator of the environmental performance of an industrial enterprise;
m is the number of groups of parameters taken into account in the assessment of environmental performance.

The method is simple and understandable. It is not specified how exactly the determination of weight coefficients will be carried out, but this does not detract from the method and the relevance of its use to solve the problem. Unambiguously, this method allows taking into account non-economic parameters that are different in physical nature when evaluating the effectiveness.

3. Weighted scoring method (ranking) (Bardahanova, 2012). This method is used and recommended in 2 cases out of 45 (in 41 of the studied sources). This method is similar to that presented in the source (Bersten & Egorova, 2007), but is more simplified. Its difference is that it does not use the mechanism of transfer to the normalized scale. All the environmental criteria are evaluated in the form of points, evaluated by an expert method. Thus, there appears a ranked number of investment projects. A similar approach of scoring and ranking is proposed to be used for ranking projects in the work of B.F.Noble (Noble et al., 2012). The disadvantage of this method may occur when determining weight coefficients depending on the chosen method (either a significant prevalence of subjective assessments or the use of mathematical weighting estimates). Both methods have the right to be used, but in a certain context there may be preferences for one or another method.

4. Indicator evaluation method (Grachev & Plyamina, 2017; Grachev, Plyamina, & V.A, 2016). This method is applied in 2 cases out of 45 (in 41 studied sources). The essence of the method lies in the assignment of points to the factors that affect the environment (by expert or accounting methods). A 10 point scale is used. 10 points is the most harmful influence (in actual terms) and 0 points – the absence of influence. The following data is used to evaluate indicators of environmental performance: natural value, specific value, indexed (relative) data,

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

aggregated data and weighted value. The system of indicators for assessing environmental efficiency consists of the following indicators assessment of the value of the effective dose of radiation (criterion of nuclear and radiation safety); indicators for assessing the health status of the population (social criterion); indicators for assessing the state of the atmosphere, the aquatic environment and the soil (ecological criterion); indicators for assessing prevented damage to the environment (environmental damage), incl. losses (social and economic) and environmental harm (economic criterion). Then, there goes the process of formation of a total integrated indicator of impact on environment. The higher this indicator, the stronger is the impact and, as a result, option is the less preferred. A similar indicator assessment of the environmental impact was made by the authors when comparing alternative methods of generating electricity (Grachev & Plyamina, 2017). It is not entirely clear from these works how the indicators are weighed when they are summarized into a comprehensive complex indicator of environmental impact. Therefore, there may appear the same shortcomings as in previous works (Bardahanova, 2012; Noble et al., 2012).

Thus, having considered the methods and mathematical tools for evaluating the effectiveness of investment projects in terms of accounting for non-economic characteristics (parameters) it is necessary to divide the evaluation parameters into two classification groups. The first group will include non-economic indicators, parameters that can be unambiguously quantified in terms of value with a high degree of probability, and therefore, they would be taken into account in the payment streams of the evaluated project. Let such a group be called in our study *a group of easily formalized non-economic characteristics (parameters, indicators).*

The second group of non-economic characteristics will include parameters, indicators that cannot be unambiguously assessed in terms of value. They cannot be quantified and taken into account in the assessment without the use of special methods, tools for transfer to normalized and (or) point scales. In our study, such a group will be called a group of *difficult formalized non-economic characteristics (parameters, indicators).* Here we have to use the existing tools, methodology or it is necessary to improve or develop a new tool for combining cost and normalized assessment, in order to make an unambiguous sound conclusion.

4. Results and Discussion

4.1. Research Statistics

So, the study of literature sources of the foreign Web of Science Core Collection database and the Russian RSCI database on the subject of research allows us to single out the following mathematical methods and their application frequency in evaluating the effectiveness of investment projects (see Table 5):

Table 5. Frequency and percentage of application of certain mathematical tooling to take into account non-economic characteristics when evaluating the effectiveness of investment projects

№№	Mathematical methods and tools	Mathematical methods and tools	Total cases	Percentage, %
1	Method of valuation of changes in macroeconomic indicators (*“Cash flow” and cost-benefit analysis* methods (*CBA*)).	Conversion into the value scale of assessments of various indicators, parameters reflecting both positive and negative effects of project implementation (gains and losses).	22	49
2	Method of multi-criteria optimization based on the use of the Monte Carlo method and data matching	A tool for solving a discrete multicriteria optimization problem at the stage of determining weight coefficients for each decision criterion.	1	2,2

3	Energy balance calculation method.	Calculation of *ROI* energy.	1	2,2
4	Methods for assessing risk and uncertainty:		8	17,9
4.1	*Scenario method (theory of games with "nature")*	Elimination of the uncertainty of investment projects' impact (IP) on the surrounding areas of activity; IP ranking.	*4*	*9*
4.2	*Risk adjustment in the discount rate*	When calculating the *NPV* of a project, the overestimated value of the discount rate (*R*) for unexpected circumstances is assumed.	*1*	*2,2*
4.3	*Risk assessment matrix method*	Matrix of qualitative risk description, risk identification. Matrix of quantitative risk assessment and implementation of gradation.	*3*	*6,7*
5	Methods of fuzzy (vague) sets		4	8.8
5.1	*TOPSIS method in combination with linguistic neutrosophic numbers (LNN)*	The method of establishing preferences in the likeness of the ideal solution when calculating the weight model. The high uncertainty of the human nature is eliminated. Ranking of risk factors.	*1*	*2,2*
5.2	*AHP- fuzzy comprehensive evaluation method*	The method of analyzing hierarchies and fuzzy complex assessment in conditions of high uncertainty. The method of pairwise comparisons in establishing the weight coefficients.	*1*	*2,2*
5.3	*TFIEOWA operator's method*	A triangular fuzzy induced Einstein operator with weighted averaging in assessing the risk of an investment project based on investor's mood.	*1*	*2,2*
5.4	*Efficiency criteria in the scales of fuzzy sets theory in the form of linguistic variable*	Effectiveness criteria are formulated in terms of fuzzy sets. Linguistic variables are used with their term-sets. More adequate reality assessment.	*1*	*2,2*
6	Methods of the aggregation theory (generalization)		9	19,9
6.1	*Desirability function method by Harrington*	The Harrington's desirability function transfers parameters different in physical essence into a single dimensionless scale according to given constraints. The method determines the generalized desirability function, which is used as an evaluation criterion (choice). A purely valuation approach is eliminated using "resultant".	*3*	*6,7*
6.2	*The method of valuation and the integral indicator (except for the function of desirability)*	Non-economic indicators are converted into dimensionless units by the valuation method. The summarizing criterion is formed as	*2*	*4,4*

ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES
ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

		a weighted average and (or) weighted geometric mean. It is necessary to calculate weight coefficients.		
6.3	*Weighted scoring method (ranking)*	Non-economic parameters are estimated by an expert method in the form of points. There is formed ranked number of projects using weighting factors without transferring to the normalized scale.	*2*	*4,4*
6.4	*Indicator evaluation method*	The factors that affect the environment are assigned points. The weighting factors and the total complex indicator of impact (evaluation criterion) are calculated.	*2*	*4,4*
7	Cases in total		45	100

Source: compiled by the authors

4.2. Recommendations for taking into account non-economic characteristics in evaluating the effectiveness of investment projects of global and national economic significance level

So, the approach of considering easily formalized non-economic characteristics becomes obvious. The *CBA* and the *Cash flow* methods allow to take into account the non-economic characteristics quantified by a particular technique in the net cash flow. It is recommended to include parameters that can be converted into a value scale to easily formalized evaluation ones with the help of the available techniques. There should be high probability of such an unambiguous transfer. For example, there can be applied ("Method of determining prevented environmental damage," 1999), for accounting prevented environmental damage, which is associated with the implementation of an investment project, an appropriate methodology, where the valuation methods of possible consequences are clearly defined, for instance, if the project was not implemented.

Projects of global and national economic significance level allow to obtain a multiplicative effect in the related fields and in the economy as a whole. This effect can be both negative and positive or also it may contain both sides at the same time. Considering the fact that the *CBA* method is substantially developed and it is often used in evaluating the effectiveness and feasibility of projects being implemented, it can be assumed that there will be ways, methods and techniques for unambiguously transferring non-economic characteristics to the value scale with a high degree of probability. In order to choose or develop such an unambiguous translation method and to avoid disagreements in the selection process, it is necessary to clarify the notion of a "high degree of probability" for our case (the case of taking into account non-economic characteristics in assessing the effectiveness of a project in the value scale). From our point of view, under a high degree of probability should be understood the following ("Method of determining prevented environmental damage," 1999):

1. The possibility of using ready-made officially approved techniques of translation, for example, "Techniques for determining prevented environmental damage", where models for converting prevented environmental damage value into a value scale are presented and justified.
2. It has been established that there will be a strictly defined nature of the functional dependence of costs on performance (mostly linear). This requires a large statistical base.
3. There is no difficulty in accounting for costs and effects distributed in time.

4. There is an ability of bringing into comparable identity when comparing several alternatives and choosing the best project.
5. There is no other uncertainty, causing doubts about the adequacy of the performance assessment, taking into account non-economic characteristics.

It should be noted that according to the statistics of the materials studied by us, then the described method of accounting for non-economic parameters in the evaluation of efficiency accounts for 49% (22 cases out of 45). Especially easily formalized non-economic parameters can be estimated using the of *CBA*, *Cash flow* methods and others. At the same time, 51% of the studied materials and articles allow us to conclude unequivocally that economic methods for accounting for non-economic characteristics in evaluating the effectiveness of investment projects cannot be dominant or even viable. Since most of the characteristics cannot be definitely with a high degree of probability (observing the conditions introduced above) transferred to the value scale of assessment. Thus, researchers use here another arsenal of mathematical tools in accounting for non-economic characteristics when evaluating the effectiveness of investments. A detailed analysis of these methods (14 mathematical tools) was carried out in the “Research” section of this article.

We can conclude that after examining the analyzed sources for the use of a mathematical toolkit, we recommend to apply : standardized scales; weight coefficients of normalized values (in the case of linear weighting); the representation of the value of the private estimation parameters in the form of fuzzy sets (linguistic variables) and integral (generalized) evaluation criterion in the process of evaluating the effectiveness of investment projects taking into account non-economic characteristics. This is necessary when taking into account assessment parameters difficult to formalize.

An important factor in the necessity to integrate everything in one quantitative calculation criterion is the fact that today information technologies occupy leading positions in all areas of activity, including in valuation activities. The speed of the introduction of innovative projects, the tight deadlines of absorption become the key factors for the development of a country or region economy. It is apparent that making a quick adequate management decision taking into account non-economic characteristics, the formalization, creation and implementation of mathematical assessment tools based on an integral criterion is extremely important.

4.3. Mathematical tooling for accounting non-economic characteristics difficultly formalized in evaluating investment projects effectiveness

We propose to use the Harrington desirability function method and fuzzy sets theory for taking into account difficultly formalized non-economic characteristics in assessing the effectiveness of investment projects of global and national economic importance. The scope of their application also extends to the accounting of parameters that are easily formalized in the value scale. The aggregation method in the form of the Harrington desirability function method (formulas (3) - (10)) allows to transfer all possible assessment parameters into a single dimensionless scale of desirability (normalized scale) if there are given the constraints and (or) desirable levels of the decision maker. The method allows to calculate the generalized desirability function of Harrington (see formula (10)), which is an integral evaluation criterion. There is a requirement : the presence of specified constraints of the decision maker. Restrictions are strict and (or) desirable levels according to one or another characteristics can be set: in the form of clear numbers; in the form of fuzzy sets (linguistic variables).

In the first case, the transferring mechanism is used:

$$Y \to Y' \to d \tag{18}$$

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

where Y is a numerical system with value of non-economic characteristics; Y' is a numerical system with intermediate normalized characteristic values, which are calculated by formulas (4), (5), (6) and (9) depending on the type of constraint (upper, lower or upper and lower); d is the function of Harrington desirability , calculated by formulas (3) and (8) depending on the type of restrictions.

The generalized integral evaluation criterion is determined by formula (10) as the geometric mean.
In the second case, the transferring mechanism is used in the form:

$$Y \to d \tag{19}$$

At the same time, all desirability of intermediate values of the linguistic variable "Non-Economic Characteristics" (hereinafter LV "NEC") can be determined either graphically (less accurately) by drawing a perpendicular line passing through the corresponding value to the intersection with the obtained desirability scale (see figure: value 30% , 47%, 55%), or analytically by the following formula:

$$d_X = d_{p1} \times \mu_{X1} + d_{p2} \times \mu_{X2} \tag{20}$$

where d_X is desirability of a calculated value from a universal linguistic variable set (LV); d_{p1}, d_{p2} - the desirability of the "threshold", "critical" values of the 1st and 2nd terms respectively, to which the value of the characteristic X belongs (with a certain value of the membership function); μ_{X1}, μ_{X2} – values of the membership functions of the 1st and 2nd terms respectively, for the X value.

The integral evaluation criterion is also determined by formula (8) as a geometric mean. This criterion allows to "throw back" a version of the project that does not comply with the strict limitation of at least one characteristic (parameter).

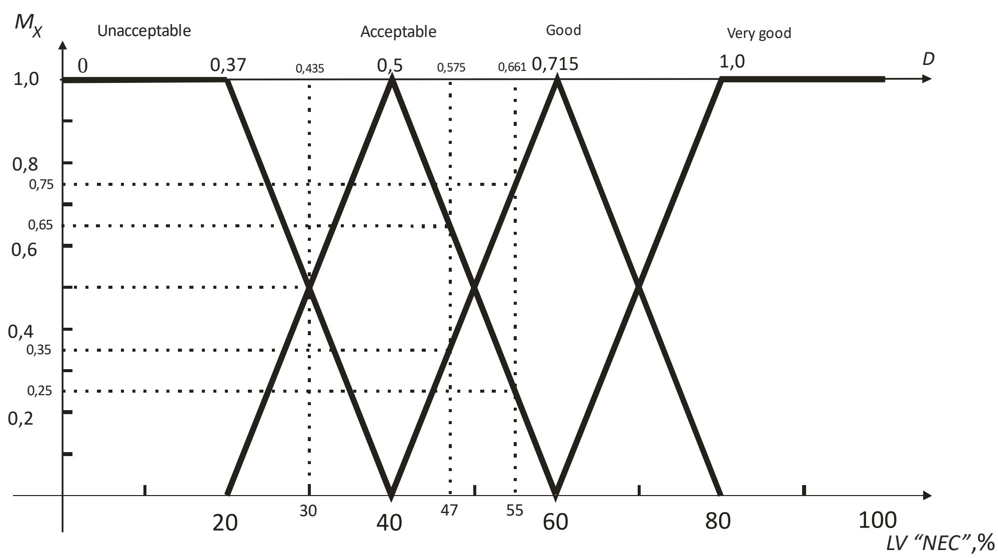

Fig.1. *Nomogram of transferring values of the linguistic variable of non-economic characteristics (LV "NEC") into the value of the desirability function (conditional example)*

Source: compiled by the authors

ISSN 2345-0282 (online) http://jssidoi.org/jesi/
2019 Volume 7 Number 2 (December)
http://doi.org/10.9770/jesi.2019.7.2(23)

This approach of accounting non-economic characteristics on a conditional or real valuation example should be considered in more detail. But for this, firstly, it is necessary to develop a mandatory set of non-economic characteristics for evaluating projects of global and national economic importance. Secondly, to prescribe a clear sequence of actions of the decision maker, i.e. evaluation method. And only then make an assessment in strict accordance with the prescribed method on a real or conditional example.

In the case when the weighted average value (the result of a linear resultant) is used as an integral evaluation criterion, then it is important to calculate the coefficients of significance (weight) of each estimated non-economic indicator (parameter). The analysis of the above-mentioned methods showed that to determine weight coefficients under conditions of high uncertainty, it is desirable to apply: an expert method with subsequent elimination of uncertainty using the *Monte Carlo* method; *AHP* method, which allows to reduce the subjectivity of the expert method of establishing weight coefficients, because a special evaluation scale for comparing alternatives is used; Technique for Order of Preference by Similarity to Ideal Solution (*TOPSIS*), which makes it possible to rank risk factors in the implementation of an investment project and to develop weighting factors for these factors.

Also of particular interest is the *AHP* method in solving the problem of choosing the optimal solution (for example, of an investment project) from the set of existing alternatives. But there is a limitation: a comparison is necessary, i.e. at least two project options are required.

Conclusion

So, the research showed:

1. The necessity to separate evaluation parameters into two classification groups. The first group will include non-economic indicators, parameters that can be unambiguously quantified in terms of value with a high degree of probability. Such a group of non-economic indicators is named by us as easily formalized characteristics. They can be taken into account by established traditional methods in the payment flows in the value scale. Criteria have been established for classifying methods for taking into account non-economic characteristics as those that with a high degree of probability can do this in the value (money) scale.
2. The second group of non-economic parameters taken into account is called difficult to formalize in the value scale, since they cannot be evaluated without preliminary procedures for transfer to the normalized scale, take into account in assessing the effectiveness of the investment project. There is also noted the importance of developing mandatory parameters that are difficult to formalize, which must be taken into account when evaluating the effectiveness and feasibility of investment projects of global and national economic importance.
3. Also, it was revealed that 51% of the considered cases of the use of mathematical tooling in evaluating the effectiveness of investment projects do not refer to value methods. This fact emphasizes the relevance and the need to apply assessment methods that allow to take into account and compare characteristics that are different in their physical nature when evaluating the effectiveness of projects, to make sound conclusions and to make reliable management decisions. In the application of particular interest are the methods of the theory of aggregation (19.9%), methods for estimating risk and uncertainty (17.9%), and methods of the theory of fuzzy sets (8.8%).
4. It is proposed to use the Harrington desirability function method as a universal method of generalizing and forming an integral evaluation criterion (and other analyzed integral evaluation criteria can also be used) to take into account non-economic characteristics in evaluating the effectiveness of investment projects of global and national economic significance. To eliminate the uncertainty in the evaluation conditions, it is proposed to use fuzzy sets in setting restrictions on the estimated characteristics. The methods of *AHP* and *TOPSIS* will be adequate for determining the weights (if necessary).

5. The next stage of the research is the development of a mandatory set of non-economic characteristics that are necessary to use when evaluating the effectiveness of investment projects of global and national economic importance.

References

Andruckiy, R. (2009). [AD HOC investment analysis based on CBA]. Retrieved from https://www.cfin.ru/finanalysis/invest/cost-benefit.shtml

Bardahanova, T. B. (2012). *Ecological aspects of the system of state support of investors*, Chita. Retrieved from https://elibrary.ru/item.asp?id=18823555

Bersten, E. V., & Egorova, T. A. (2007). Assessment of the environmental efficiency of the organizational structure of an industrial enterprise. *Russian Economic Online Journal* (4), 1-8. Retrieved from https://elibrary.ru/item.asp?id=19014775

Costanza, R. (2006). Thinking broadly about costs and benefits in ecological management. *Integrated Environmental Assessment and Management, 2*(2), 166-173. http://dx.doi.org/10.1002/ieam.5630020209

Droj, L., & Droj, G. (2015). Assessment of decision making for analysis of European funded investment projects - Case study on Romanian companies. *Emerging Markets Queries in Finance and Business 2014,* Emqfb 2014, 32, 1248-1257. http://dx.doi.org/10.1016/s2212-5671(15)01502-6

Eddelani, O., El Idrissi, N. E., Monni, S. (2019). Territorialized forms of production in Morocco: provisional assessment for an own model in gestation. *Insights into Regional Development,* 1(1), 6-18. https://doi.org/10.9770/ird.2019.1.1(1)

Epishkina, K. M. (2010). Estimation of public efficiency of rail transport of a megacity. *Region: Economics and Sociology* (1), 255-272. Retrieved from http://ecsocman.hse.ru/text/31619073/

Gert, A. A., Suprunchik, N. A., Nemova, O. G., & Kuz'mina, K. N. (2009). Valuation of oil and gas fields and subsoil blocks taking into account uncertainty and risks. *Subsoil use of the XXI century* (2), 49-57. Retrieved from https://elibrary.ru/item.asp?id=13001885

Grachev, V. A., & Plyamina, O. V. (2017). Global environmental problems, environmental safety and environmental efficiency of energy. *The age of globalization* (1(21)), 86-97. Retrieved from https://cyberleninka.ru/article/n/globalnye-ekologicheskie-problemy-ekologicheskaya-bezopasnost-i-ekologicheskaya-effektiv-nost-energetiki

Grachev, V. A., Plyamina, O. V., & Lobkovskiy, V. A. (2016). Indicative assessment of the environmental effectiveness of measures to ensure environmental safety. *Issues of modern science and practice* (3(61)), 21-30. Retrieved from https://istina.msu.ru/publications/article/48439952/

Harrington, E. C. (1965). The desirable function. *Industrial Quality Control, 21*(10), 494-498.

Hu, Q. G., Zhong, Y., Wang, Z., & Wu, J. P. (2016). Research on the selection mechanism of the agent based on AHP- fuzzy comprehensive evaluation method. *Proceedings of the 2015 6th International Conference on Manufacturing Science and Engineering, 32*, 76-81.

Huging, H., Glensor, K., & Lah, O. (2014). Need for a holistic assessment of urban mobility measures - Review of existing methods and design of a simplified approach. *Sustainable Mobility in Metropolitan Regions, Mobil.Tum 2014, 4*, 3-13. http://dx.doi.org/10.1016/j.trpro.2014.11.001

Hwang, C.-L., & Yoon, K. (1981). *Multiple Attribute Decision Making* (Vol. 186). Berlin, Heidelberg: Springer Berlin Heidelberg.

Jones, H., Moura, F., & Domingos, T. (2014). Transport infrastructure project evaluation using cost-benefit analysis. *Transportation: Can We Do More with Less Resources? - 16th Meeting of the Euro Working Group on Transportation - Porto 2013, 111*, 400-409. http://dx.doi.org/10.1016/j.sbspro.2014.01.073

Joseph, C., Gunton, T., & Rutherford, M. (2015). Good practices for environmental assessment. *Impact Assessment and Project Appraisal, 33*(4), 238-254. http://dx.doi.org/10.1080/14615517.2015.1063811

Kharisova, A. R., Puryaev, A. S., & IOP. (2014). Competitiveness assessment of engineering products. In *Innovative Mechanical Engineering Technologies, Equipment and Materials-2013* (Vol. 69). Retrieved from https://iopscience.iop.org/article/10.1088/1757-899X/69/1/012020

Kibalov, E. B., Glushhenko, K. P., & Goryachenko, V. I. (2015). The project of reconstruction of the Transsib as an object of evaluation of public efficiency. *The World of Economics and Management, 15*(2), 35-47. Retrieved from https://cyberleninka.ru/article/n/proekt-rekonstruktsii-transsiba-kak-obekt-otsenki-obschestvennoy-effektivnosti

Kibalov, E. B., & Shibikin, D. D. (2017). Evaluation of the effectiveness of large-scale investment projects in the context of conceptual design. *Bulletin of the South Ural State University. Series: Computer technologies, management, radio electronics, 17*(3), 99-108. Retrieved from https://cyberleninka.ru/article/n/otsenka-effektivnosti-krupnomasshtabnyh-investitsionnyh-proektov-v-kontekste-kontseptualnogo-proektirovaniya

Kogan, A. B. (2013). Analysis of the global and local effectiveness of a large-scale investment project. *Region: Economics and Sociology* (2(78)), 266-282. Retrieved from http://www.sibran.ru/upload/iblock/93c/93c0283f1033f3071a0ab898b29d517f.pdf

Korytarova, J., & Hromadka, V. (2014). The Economic Evaluation of Megaprojects - Social and Economic Impacts. *Selected Papers from the 27th Ipma (International Project Management Association), 119*, 495-502. http://dx.doi.org/10.1016/j.sbspro.2014.03.055

Korytarova, J., & Papezikova, P. (2015). Assessment of Large-Scale Projects Based on CBA. *Conference on Enterprise Information Systems/International Conference on Project Management/Conference on Health and Social Care Information Systems and Technologies, Centeris/Projman / Hcist 2015, 64*, 736-743. http://dx.doi.org/10.1016/j.procs.2015.08.602

Kosov, V. V., Livshic, V. N., & Shahnazarova, A. G. (2000). *Methodical recommendations for evaluating the effectiveness of investment projects* (2 ed.). Moscow: JSC «NPO «Izdatel'stvo «Jekonomika». Retrieved from https://files.stroyinf.ru/Data2/1/4294849/4294849734.pdf

Liang, W. Z., Zhao, G. Y., & Wu, H. (2017). Evaluating Investment Risks of Metallic Mines Using an Extended TOPSIS Method with Linguistic Neutrosophic Numbers. *Symmetry-Basel, 9*(8). http://dx.doi.org/10.3390/sym9080149

Medvedev, P. V. (2015). Tools for accounting for social and environmental aspects of economic security. *Problems of market economy* (1), 47-53. Retrieved from https://docplayer.ru/25917617-Instrumentov-ucheta-socialnyh-i-ekologicheskih-aspektov-obespecheniya-ekonomicheskoy-bezopasnosti.html

Mendecka, B., & Koziol, J. (2015). Application of the method of data reconciliation for minimizing uncertainty of the weight function in the multicriteria optimization model. *Archives of Thermodynamics, 36*(1), 83-92. http://dx.doi.org/10.1515/aoter-2015-0006

[Method of calculation of indicators and use of criteria of efficiency of the investment projects applying for receiving the state support at the expense of means of Investment fund of the Russian Federation] (2009). Retrieved from https://znaytovar.ru/gost/2/Prikaz_13982n_Metodika_raschet.html

[Method of determining prevented environmental damage] (1999). Retrieved from http://docs.cntd.ru/document/1200035561

[Methodical recommendations for evaluating the effectiveness of investment projects] (2008). Retrieved from http://aidarp.ru/документы/УМК/project03redMR.pdf

Mironyuk, S. G. (2015). Geological dangers of the developed deposits of the eastern shelf of Sakhalin Island: identification and principles of mapping. *Scientific and technical collection "News of gas science"*(2(22)), 113-117. Retrieved from http://vesti-gas.ru/sites/default/files/attachments/vgn-2-22-2015-113-117.pdf

Noble, B. F., Gunn, J., & Martin, J. (2012). Survey of current methods and guidance for strategic environmental assessment. *Impact Assessment and Project Appraisal, 30*(3), 139-147. http://dx.doi.org/10.1080/14615517.2012.705076

Novikova, T. S. (2005). Methodology for assessing the social effectiveness of innovative projects. *Innovations* (4(81)), 86-90. Retrieved from https://cyberleninka.ru/article/n/metodika-otsenki-obschestvennoy-effektivnosti-innovatsionnyh-proektov

Orlova, E. R., & Safin, R. N. (2011). Evaluation of public effectiveness of investment projects in modern Russia. *Proceedings of the Institute of System Analysis of the Russian Academy of Sciences, 61*(3), 53-64. Retrieved from http://www.isa.ru/proceedings/images/documents/2011-61-3/orlova.pdf

Pavlov, V. A. (2002). Evaluation of the environmental efficiency of investment projects and the social discount rate. *Evaluation issues* (2), 30-37. Retrieved from https://ru-sroroo-9a2cc46a.storage-download.googleapis.com/iblock/3d8/vo2_02.pdf

Petrova, Y. A. (2016). Assessment of public efficiency of investment projects. *Oil, gas and business* (5), 58-63. Retrieved from http://ngb.gubkin.ru/archiv/files/may_2016.pdf

Platon, V., Frone, S., & Constantinescu, A. (2014). Financial and economic risks to public projects. *1st International Conference 'Economic Scientific Research - Theoretical, Empirical and Practical Approaches', Espera 2013, 8,* 204-210. http://dx.doi.org/10.1016/s2212-5671(14)00082-3

Puryaev, A. S. (2009). *Theory and Methodology compromise efficiency assessment of investment projects in mechanical engineering*. Autoabstract of doctoral dissertation. Saint-Petersburg State University of Engineering and Economics. St. Petersburg. Retrieved from http://aidarp.ru/%D0%B4%D0%BE%D0%BA%D1%83%D0%BC%D0%B5%D0%BD%D1%82%D1%8B/%D0%9F%D1%83%D0%B1%D0%BB%D0%B8%D0%BA%D0%B0%D1%86%D0%B8%D0%B8/AvtoreferatPuryaev_A.S.pdf

Puryaev, A. S. (2015). The mathematical apparatus of compromise of efficiency estimation of investment projects. *International Business Management, 9*(5), 856-861. Retrieved from http://medwelljournals.com/abstract/?doi=ibm.2015.856.861

Romanelli, T. L., & Milan, M. (2010). Energy performance of a production system of eucalyptus. *Revista Brasileira De Engenharia Agricola E Ambiental, 14*(8), 896-903. http://dx.doi.org/10.1590/s1415-43662010000800015

Selle, T., & Zimmermann, J. (2003). A bidirectional heuristic for maximizing the net present value of large-scale projects subject to limited resources. *Naval Research Logistics, 50*(2), 130-148. http://dx.doi.org/10.1002/nav.10052

Serikov, P. Y. (2013). Estimation of public efficiency of construction of main oil pipelines. *Science and technologies of pipeline transport of oil and oil products* (2(10)), 84-90. Retrieved from http://giprotruboprovod.transneft.ru/u/articles_file/11751/serikov-korneeva-petrova_nt_3_15__2014-2.pdf

Serikov, P. Y., Korneeva, S. V., & Petrova, Y. A. (2014). Estimation of investment projects from the point of view of public efficiency taking into account multiplicative effects. *Science and technologies of pipeline transport of oil and oil products* (3(15)), 108-115. Retrieved from https://elibrary.ru/item.asp?id=21995354

Velikaya, E. G., & Papyan, A. G. (2015). Estimated approach to the effectiveness of the entrepreneurial cluster. *Azimuth Research: Economics and Management* (2), 16-20. Retrieved from https://elibrary.ru/item.asp?id=23756668

Woods, A. (2015). [Introduction to Monte Carlo Methods]. Retrieved from https://www.analyticbridge.datasciencecentral.com/profiles/blogs/introduction-to-monte-carlo-methods

Xu, X. Y., Yang, Z. R., & Hao, L. Z. (2017). Research on the risk evaluation of the risk investment project based on the investor sentiment with triangular fuzzy information. *Journal of Intelligent & Fuzzy Systems, 33*(6), 3201-3208. http://dx.doi.org/10.3233/jifs-161111

Zhevlatova, P. N. (2013). Estimation of public efficiency of the electric power industry project taking into account state support. *International Scientific Journal* (3), 33-39. Retrieved from https://elibrary.ru/item.asp?id=19061873

Aknowledgements

The reported study was funded by RFBR according to the research project № 18-010-00018.

Aidar S. PURYAEV, Dr.Sci. (Economics), Professor of the Department of Production Management of the Kazan Federal University (Kazan, Russian Federation). Research interests: evaluation of investment and innovation projects; efficiency mark; accounting when assessing non-economic characteristics.
ORCID ID: https://orcid.org/0000-0003-1949-5763

Arslan A. PURYAEV, Student of the Department Applied Geodesy of the Moscow State University of Geodesy and Cartography (Moscow, Russian Federation). Research interests: evaluation of investment and innovation projects, applied geodesy, programming.
ORCID ID: https://orcid.org/0000-0002-2004-5703