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Formalization of Requirements for Spatial Development Investment Projects

Vladimir Kalugin
Department of Applied Economics and Economic Security
Belgorod State National Research University
Belgorod, Russia
kalugin@bsu.edu.ru

German Poddubny
Department of Applied Economics and Economic Security
Belgorod State National Research University
Belgorod, Russia
1334524@bsu.edu.ru

Aleksandra Dubskaya
Department of Applied Economics and Economic Security
Belgorod State National Research University
Belgorod, Russia
1065145@bsu.edu.ru

Eugeniy Bukhvald
Department of Federal Relations and Regional Development
Institute of Economics, Russian Academy of Sciences
Moscow, Russia
buchvald@mail.ru

***Abstract*— One of the most important tasks in economy is to assess the economic efficiency of investment projects. Evaluation of the effectiveness of investment projects is of utmost importance at the pre-investment stage of the life cycle. However, the amount and nature of information available at this stage does not allow for the full application of traditional performance assessment methods based on discounting future cash flows (DCF-methods). However, these methods can be used by analyzing the information entity of each of the criteria underlying DCF-methods. At the same time, a set of these criteria is necessary but not enough, because during the stage of selection of investment projects by potential investors and decisions on their inclusion in financing programs, the stage of environmental screening plays a special role. At the same time, the main task is to define environmental criteria, which in most cases are not quantifiable, which leads to the need to process qualitative information. And besides, when assessing the effectiveness of investment projects, some criteria have the nature of limitations. In effect, criteria and restrictions are requirements that determine the needs of interested parties (stakeholders) – users, consumers, suppliers, developers, and businesses themselves. Therefore, the article uses the concepts of requirements-criteria and requirements-restrictions. The article presents a formal tool for describing various requirements and how to integrate them into a single model for assessing the effectiveness of investment projects at the pre-investment stage. As a formal tool for describing various requirements, the mathematical apparatus of fuzzy set theory and the methodology of system analysis of hierarchical structures are used. The use of fuzzy set theory as an instrumental basis for describing various requirements is although it does not eliminate the subjective nature of the concepts with which decision makers deal, it gives them the means to describe these subjective concepts in a rational way. The use of the proposed method of formalizing requirements and the formation of an assessment of the effectiveness of investment projects based on it is demonstrated on a model example.**

Keywords—Discounted Cash Flow - methods (DFM-methods), environmental criteria, stakeholders, requirements-criteria, requirements-restrictions, fuzzy sets, degree of belonging to fuzzy set, system analysis of hierarchical structures, scripting method, subjective scale of qualitative gradations, latent vector, eigenvalue of pairwise comparison matrix, operation of crossing fuzzy sets (conjunction rule), weighted intersection of fuzzy sets.

I. INTRODUCTION

Universally known, that one of the most important tasks in economy is to assess the economic effectiveness of investment projects (IP) implemented in various fields of activity, including within the framework of spatial development of territories [1, 2, 3]. How far-sighted, rational, economically sound and efficient investment decisions depend to a large extent not only on the future of specific enterprises, firms, regions, but also on the future of the country's economy as a whole, since their functioning affects the behavior of other actors in the economic community, socio-economic and natural environment [4]. At the same time, it should be emphasized critical importance of IP performance assessment in the pre-investment phase, because it is on the quality of this assessment that the success of the subsequent IP implementation depends: this step selects from the list of alternative IP's the most efficient, which allows you to abandon the "non-viable" project. However, the amount and nature of information available at this stage does not allow full application of traditional IP performance assessment methods based on discounting future cash flows (DCF- methods): NPV – Net Present Value, PI – Profitability Index, IRR – Internal Rate of Return, DPP – Discount Payback Period. Besides, should be noted, in the process of analyzing an IP, only in rare cases will there be a situation when it is simultaneously acceptable from the position of all the criteria under consideration. As a rule, different criteria will give different IP ordering (ranking) and show different make-reject decisions. Therefore, there is a problem of selecting one leading criterion or prioritizing their use [2].

In this regard, many solid firms such as IBM, GE, «Royal Dutch Petroleum», calculate and analyze all criteria, since each of them provides additional relevant information that makes up their "information entity" [1, 5,6]: NPV is important because it shows the project-generated increase in shareholder wealth and is the best characteristic of return on invested capital; PI also provides information on the "Project Security Limit Reserve" as it measures profit per monetary unit of investment; IRR, being a relative indicator, estimates the return on investment, and it is this indicator that many managers, especially non-specialists in the field of finance, seem to be the most preferable. Besides, it contains information about the "project security reserve," which is not characteristic of NPV; DPP provides information on project risk and liquidity - long payback period means, firstly, that the invested funds will be linked over many years, therefore, the project is relatively illiquid, secondly, project revenues should be projected for the long term, which means significant project risk. Thus, there is a new problem of accounting under a single model of all private criteria, the problem of multi-criterion IP assessment. In the work [7] proposed multi-criterion method of IP assessment for pre-investment stage (stage of development of investment proposal and declaration of intent), characterized by the minimum depth of development of the investment proposal, meaning the complete absence of a reliable cash forecast for each of the analyzed IP. At the same time, a set of private IP evaluation criteria is obtained naturally by analyzing the information essence of each of the indicators DCF-methods. At the same time, in each case of an investment decision, one criterion turns out to be more significant than the other, and, therefore, must have funds, which make it possible to assess this significance [1]. The conceptual and methodological basis for taking into account the information contained in each of the private criteria and determining the significance of the private criteria themselves in the proposed method are the provisions of the methodology for systematic analysis of hierarchical structures (Analytic Hierarchy Process — AHP) [8, 9]. An attempt to solve the problem of multicriterial evaluation was also made in another work of the same author [10]. It proposes to use the idea of multi-mode technology, which is an actively developing area of the theory of optimal control. At the same time, unlike the traditional use of multi-mode technology, which involves the use of not one method in the process of solving a problem, but a sequence of different optimization methods, it is proposed to combine based on the additionality ratio of DCF methods, each of which gives additional relevant information, which will improve the efficiency of investment decision-making. However, a set of private criteria, which are the criteria DCF-methods, is necessary, but not enough, as the valuation process, along with financial indicators, increasingly addresses many other aspects of investment projects. So, at the stage of selection of investment projects by potential investors and making decisions on their inclusion in financing programs, the stage of environmental screening plays a special role. At the same time, the main task is to determine the degree of compliance of existing investment projects with environmental criteria and to establish their priority. The solution of this problem is carried out in conditions of uncertainty, because the state of the environment in most cases is not quantifiable and leads to the need to process information of a qualitative nature. Therefore, a set of evaluation quantitative criteria should be supplemented by qualitative criteria. Besides, when evaluating the effectiveness of IP, some criteria have the nature of limitations. For example, DPP is showing IP with a life cycle of at least a discounted payback period at least provides return on investment. Thus, in order to improve the quality of multi-criteria evaluation of IP performance, it is necessary to consider not only criteria, both quantitative and qualitative, but also restrictions.

Criteria and restrictions are requirements that determine the needs of interested parties (stakeholders) – users, consumers, suppliers, developers and the business itself, – which are necessary for them [11]. Good set stakeholder requirements may provide a brief and non-technical description of what will be developed at a level that is available for understanding high management. In this regard, it should be noted that in order to provide such an understanding, requirements are in most cases written in the "normal" language, which introduces its problems, namely, the need to fully and unequivocally identify problems and record needs without using the usual and professional language [11]. This circumstance fully applies to investment projects for the spatial development of territories, the user requirements for which are often formed by ordinary citizens living in the relevant territory and whose interests affect the investment project. Agreed requirements provide the basis for system development planning and acceptance upon completion. Requirements are necessary when compromises have to be made, and they are vital when changes have to be made in the development process, which is virtually inevitable for any of the projects. Thus, in order to obtain a comprehensive assessment of IP performance at the pre-investment stage, it is necessary to have a formal tool for describing various requirements and means for integrating them into a single assessment model. The result of such integration should be a single comprehensive assessment of IP performance, in which each private criterion used characterizes only a separate aspect of the implementation of the investment proposal. In this article as a formal tool for describing various requirements for spatial development investment projects, the mathematical apparatus of fuzzy set theory and the methodology of system analysis of hierarchical structures are used [8, 12]. At the same time, we will distinguish between requirements-criteria and requirements-restrictions. The use of fuzzy set theory as an instrumental basis for describing various requirements is that although it does not eliminate the subjective nature of the concepts that decision makers deal with, it gives them the means to describe these subjective concepts in a rational way [13, 14]. For the first time the mathematical apparatus of fuzzy set theory was proposed in Bellman and Zade's article [15] for problems of multi-criterion choice. It demonstrated the possibilities of presenting criteria and constraints through fuzzy sets that combine elements of subjective preferences. At the same time, the procedure for integrating criteria and constraints into a single evaluation model is considered as a problem of aggregating (combining) fuzzy sets by conducting theoretical-multiple operations on them. Bellman and Zade proposed using a conjunction rule with n criteria and m constraints as an aggregation operation.

II. METHODS

In this article as a formal tool for describing various requirements for spatial development investment projects, the mathematical apparatus of fuzzy set theory and the methodology of system analysis of hierarchical structures are used.

III. MAIN PART

We set out a method for formalizing the requirements for investment projects of spatial development of territories, based on the mathematical apparatus of fuzzy set theory and the methodology of system analysis of hierarchical structures.

Let it be evaluated *as investment* projects (IP_1, ..., IP_m) and choose the best of them in terms of *n* requirements-criteria $K = \{K_1, ..., K_n\}$ and *l* requirements-restrictions $G = \{G_1, ..., G_l\}$.

In this case, two cases are possible:

1. Requirements-criteria and requirements-restrictions have the same degree of importance for decision maker;

2. Requirements-criteria and requirements-restrictions have different degrees of importance for decision makers.

First case. Present each requirement with fuzzy sets defined on a universal set of investment projects. They will be denoted, as well as the names of the requirements, but we will write them in italics together with bold:

$\boldsymbol{K_1} = \{IP_1/\mu_{K1}(IP_1), IP_2/\mu_{K1}(IP_2), ..., IP_m/\mu_{K1}(IP_m)\}$,

....,

$\boldsymbol{K_i} = \{IP_1/\mu_{Ki}(IP_1), IP_2/\mu_{Ki}(IP_2), ..., IP_m/\mu_{Ki}(IP_m)\}$,

....,

$\boldsymbol{K_n} = \{IP_1/\mu_{Kn}(IP_1), IP_2/\mu_{Kn}(IP_2), ..., IP_m/\mu_{Kn}(IP_m)\}$,

$\boldsymbol{G_1} = \{IP_1/\mu_{G1}(IP_1), IP_2/\mu_{G1}(IP_2), ..., IP_m/\mu_{G1}(IP_m)\}$,

....,

$\boldsymbol{G_i} = \{IP_1/\mu_{Gi}(IP_1), IP_2/\mu_{Gi}(IP_2), ..., IP_m/\mu_{Gi}(IP_m)\}$,

....,

$\boldsymbol{G_l} = \{IP_1/\mu_{Gl}(IP_1), IP_2/\mu_{Gl}(IP_2), ..., IP_m/\mu_{Gl}(IP_m)\}$,

where $\mu_V(IP_i)$ – function (degree) of belonging to the IPi fuzzy set V (V takes values from a set $\{K_1, ..., K_n, G_1, ..., G_l\}$).

To obtain estimates $\mu_V(IP_i)$, relating to fuzzy sets that meet quantitative requirements-criteria, it is proposed to use a procedure based on the scenario method. Let it be necessary to obtain estimates $\mu_V(IP_i)$ for fuzzy set $\boldsymbol{K_i}$.

For corresponding to this set criterion $\boldsymbol{K}_i$ expert generates three scenarios: optimistic, pessimistic and real. According to these scenarios are generated relevant assessments IP regarding the criterion $\boldsymbol{K}_i$

TABLE I. ESTIMATES IP REGARDING THE CRITERION KI, CORRESPONDING TO THREE SCENARIOS

Criterion $\boldsymbol{K}_i$	Estimates				
Scenarios	IP_1	...	IP_i	...	IP_m
Optimistic	$W^{max}(IP_1/\boldsymbol{K}_i)\cdot$	...	$W^{max}(IP_i/\boldsymbol{K}_i)\cdot$	...	$W^{max}(IP_m/\boldsymbol{K}_i)\cdot$
Pessimistic	$W^{min}(IP_1/\boldsymbol{K}_i)\cdot$	...	$W^{min}(IP_i/\boldsymbol{K}_i)\cdot$	...	$W^{min}(IP_m/\boldsymbol{K}_i)\cdot$
Real	$W(IP_1/\boldsymbol{K}_i)\cdot$	...	$W(IP_i/\boldsymbol{K}_i)\cdot$	...	$W(IP_m/\boldsymbol{K}_i)\cdot$

Appropriate degrees of affiliation IP_i fuzzy set K_i we will get as follows:

$\mu_{Ki}(IP_i) = (W(IP_i/\boldsymbol{K}_i)\cdot - W^{min}(IP_i/\boldsymbol{K}_i))/(W^{max}(IP_i/\boldsymbol{K}_i)\cdot - W^{min}(IP_i/\boldsymbol{K}_i))$.

To obtain estimates $\mu_V(IP_i)$, relating to fuzzy sets, meeting qualitative requirements-criteria, it is proposed to use the following procedure. Let's assume, for all qualitative criteria requirements, it is sufficient to have a subjective scale having the following qualitative gradations:

- «low» – L;
- «low medium» – LM;
- «medium» – M;
- «high medium» – HM;
- «high» – H.

Let the considered IP from the point of view of this scale received according to some criterion $\boldsymbol{K}_i$ the following qualitative evaluations:

$IP_1 \to M$; $IP_2 \to LM$; … $IP_m \to HM$.

To obtain quantitative estimates IP from the position of the criterion $\boldsymbol{K}_i$, it is necessary to display a subjective scale with qualitative gradations on a numerical scale in a mutually unambiguous way. For this purpose, we will use the methodology AHP.

Calculated eigenvector ($\boldsymbol{W} = (w_1, w_2, w_3, w_4, w_5)$), corresponding to the maximum eigenvalue of the matrix of paired comparisons of qualitative gradations, will determine their mapping to a numerical scale as follows (table 2.).

TABLE II. CORRESPONDENCE OF QUALITATIVE GRADATIONS TO NUMERICAL VALUES

Gradation	L	LM	M	HM	H
W	w_1	w_2	w_3	w_4	w_5

Relevant valuations IP from the position of the criterion $\boldsymbol{K}_i$ are obtained as follows:

$IP_1 \to M \to w_3$; $IP_2 \to LM \to w_2$; … $IP_m \to HM \to w_4$.

Procedure for obtaining assessments $\mu_V(IP_i)$, relating to fuzzy sets, that meet the requirements-restrictions somewhat like the procedure for obtaining assessments $\mu_V(IP_i)$, relating to fuzzy sets that meet quantitative criteria.

The difference is that no scripting is required, to generate $W^{min}(IP_i/\boldsymbol{K}_i))$, $W^{max}(IP_i/\boldsymbol{K}_i)$ the barrier values that are formulated in the restriction itself are used.

After the relevant assessments are generated $\mu V(IPi)$ for each fuzzy set, can be stated, fuzzy sets are formed.

The rule of choosing the best IP according to the Bellman and Zad approach can be represented as the intersection of these fuzzy sets:

$$\boldsymbol{D} = \boldsymbol{K_1} \cap ... \cap \boldsymbol{K_n} \cap \boldsymbol{G_1} \cap ... \cap \boldsymbol{G_l}.$$

It is known, the operation of crossing fuzzy sets corresponds to the operation of taking a minimum on a set of degrees of belonging of elements to these sets:

$$\mu_D(IP_i) = \min(\mu_V(IP_i)).\ i = 1, ..., m.$$

Therefore, the best IP will be the IP* investment project that has the most ownership function value:

$IP^* = Argmax(\mu_D(IP_i)),\ i = 1, ..., m.$

Second case. Criteria and restrictions are of different importance for decision makers. In this case, the best IP selection rule can be represented as *weighted intersection* fuzzy sets:

$\boldsymbol{D} = \boldsymbol{K_1}^{\alpha 1} \cap ... \cap \boldsymbol{K_n}^{\alpha n} \cap \boldsymbol{G_1}^{\alpha n+1} \cap ... \cap \boldsymbol{G_1}^{\alpha n+l}$,

where $\alpha_i = p \cdot w_i$,

wi – weights of relative importance of the corresponding requirements,

p – scaling coefficient, equal to the sum of requirements-criteria and requirements-restrictions (in this case p = n+l);

Coefficients' relative importance requirements wi can be defined, using methodology AHP.

Let us describe the proposed method of formalizing requirements and the formation of an IP performance assessment based on it on the following model example.

Example. Let it be necessary to evaluate five investment projects (IP1, ..., IP5) and assess their effectiveness in terms of three criteria NPV, IRR, PI and two restrictions of specified indicators DPP и INV (qualitative requirement-restriction «Impact on the environment»).

At the same time, two cases are possible:

1) requirements-criteria and requirements-restrictions have the same degree of importance for decision makers;

2) requirements-criteria and requirements-restrictions have the same degree of importance for decision makers.

First case. Requirements-criteria and requirements-restrictions have the same degree of importance for decision makers.

Present IP estimates for each requirement-criteria and requirement-constraints with fuzzy sets:

$\boldsymbol{NPV} = \{IP_1/\mu_{NPV}(IP_1), IP_2/\mu_{NPV}(IP_2),..., IP_5/\mu_{NPV}(IP_5)\}$,

$\boldsymbol{IRR} = \{IP_1/\mu_{IRR}(IP_1), IP_2/\mu_{IRR}(IP_2),..., IP_5/\mu_{IRR}(IP_5)\}\}$,

$\boldsymbol{PI} = \{IP_1/\mu_{PI}(IP_1), IP_2/\mu_{PI}(IP_2),..., IP_5/\mu_{PI}(IP_5)\}$,

$\boldsymbol{DPP} = \{IP_1/\mu_{DPP}(IP_1), IP_2/\mu_{DPP}(IP_2),..., IP_5/\mu_{DPP}(IP_5)\}$,

$\boldsymbol{INV} = \{IP_1/\mu_{INV}(IP_1), IP_2/\mu_{INV}(IP_2),..., IP_5/\mu_{INV}(IP_5)\}$.

Functions $\mu_V(IP_i)$, in essence, there are estimated IP in terms of some requirement-criteria and requirement-limitations *V* (*V* = NPV, IRR, PI, DPP, INV).

Suppose for certainty that these valuations received the following values (table 3).

TABLE III. ESTIMATES IP BY REQUIREMENTS NPV, IRR, PI, DPP, INV

	IP_1	IP_2	IP_3	IP_4	IP_5
NPV	0,3	0,2	0,6	0,7	0,5
IRR	0,6	0,5	0,5	0,3	0,4
PI	0,5	0,6	0,2	0,4	0,6
DPP	0,6	0,4	0,7	0,5	0,4
INV	0,7	0,3	0,4	0,8	0,7

Based on available estimates, the following fuzzy sets can be determined:

$\boldsymbol{NPV} = \{IP_1/0{,}3, IP_2/0{,}2, IP_3/0{,}6, IP_4/0{,}7, IP_5/0{,}5\}$,

$\boldsymbol{IRR} = \{IP_1/0{,}6, IP_2/0{,}5, IP_3/0{,}5, IP_4/0{,}3, IP_5/0{,}4\}$,

$\boldsymbol{PI} = \{IP_1/0{,}5, IP_2/0{,}6, IP_3/0{,}2, IP_4/0{,}4, IP_5/0{,}6\}$,

$\boldsymbol{DPP} = \{IP_1/0{,}6, IP_2/0{,}4, IP_3/0{,}7, IP_4/0{,}5, IP_5/0{,}4\}$,

$\boldsymbol{INV} = \{IP_1/0{,}7, IP_2/0{,}3, IP_3/0{,}4, IP_4/0{,}8, IP_5/0{,}7\}$.

From here, the rule of choosing the best IP can be represented as the intersection of these fuzzy sets:

$\boldsymbol{D} = \boldsymbol{NPV} \cap \boldsymbol{IRR} \cap \boldsymbol{PI} \cap \boldsymbol{DPP} \cap \boldsymbol{INV}$.

It is known, the operation of crossing fuzzy sets corresponds to the operation of taking a minimum on a set of degrees of belonging of elements to these sets:

$$\mu_D(IP_j) = \min_{V} (\mu_V(IP_j)),$$

V = (NPV, IRR, PI, DPP, INV), $j = 1, ..., 5$.

Therefore, the best IP will be the IP* investment project that has the most ownership function value:

$\mu_D(IP^*) = \max (\mu_D(IP_j)),\ j = 1, ..., 5.$

Find values μ_D for each IP:

$\mu_D(IP_1) = \min (0{,}3; 0{,}6; 0{,}5; 0{,}6; 0{,}7) = 0{,}3$,

$\mu_D(IP_2) = \min (0{,}2; 0{,}5; 0{,}6; 0{,}4; 0{,}3) = 0{,}2$,

$\mu_D(IP_3) = \min (0{,}6; 0{,}5; 0{,}2; 0{,}7; 0{,}4) = 0{,}2$,

$\mu_D(IP_4) = \min (0{,}7; 0{,}3; 0{,}4; 0{,}5, 0{,}8) = 0{,}3$,

$\mu_D(IP_5) = \min (0{,}5; 0{,}4; 0{,}6; 0{,}4; 0{,}7) = 0{,}4$.

From here we get:

$$\mu_D(IP^*) = \max (0{,}3; 0{,}2; 0{,}2; 0{,}3; 0{,}4) = 0{,}4.$$

Therefore, the most effective is $IP_5 = IP^*$.

Second case. Requirements-criteria and requirements-restrictions have the same degree of importance for decision makers.

In this case, the best IP selection rule can be represented as *weighted intersection* fuzzy sets:

$\boldsymbol{D} = \boldsymbol{NPV}^{\alpha 1} \cap \boldsymbol{IRR}^{\alpha 2} \cap \boldsymbol{PI}^{\alpha 3} \cap \boldsymbol{DPP}^{\alpha 4} \cap \boldsymbol{INV}^{\alpha 5}$,

where $\alpha_i = p \cdot w_i$, w_i – weights of relative importance of relevant criteria and limitations,

p – scaling coefficient, equal to the sum of criteria and restrictions (in this case $p = 5$);

V^{α} – the result of the construction of a fuzzy set *V* to degree α.

Coefficients relative importance of criteria w_i can be defined using methodology AHP.

Let's assume, the expert built the following matrix of paired comparisons of criteria and constraints (NPV, IRR, PI, DPP, INV) relative to the leading target (table 4).

TABLE IV. MATRIX OF PAIRED COMPARISONS OF CRITERIA AND CONSTRAINTS ON THE TARGET

Purpose	NPV	IRR	PI	DPP	INV
NPV	1	2	4	6	7
IRR	1/2	1	2	3	5
PI	1/4	1/2	1	4	3
DPP	1/6	1/3	1/4	1	1
INV	1/7	1/5	1/3	1	1

We find the maximum eigenvalues, IS coefficients, OS and eigenvector corresponding to the maximum eigenvalue represented above the matrix of paired comparisons.

The results of the obtained calculations are presented in table 5.

TABLE V. PRIORITY OF CRITERIA AND LIMITATIONS ON THE LEADING OBJECTIVE

Criterion	Latent vector (W_k)	MAX eigenvalue	IS	OS
NPV	0,438	5,269	0,067	0,060
IRR	0,252			
PI	0,192			
DPP	0,060			
INV	0,059			

By analyzing the values of the IC coefficients, the OS can be concluded that the matrix is agreed and, therefore, the judgments of experts regarding the importance of criteria and restrictions can be considered quite logical, and the results ("weights" of criteria and restrictions) are sufficiently justified.

Calculate values $\alpha_i = p \cdot w_i$ at $p = 5$, we erect fuzzy sets to the appropriate degrees (α_i), find a weighted intersection of sets in the form of a fuzzy set ***D***.

The results of the calculations are conveniently presented as a table (table 6.).

TABLE VI. BUILD DEGREES OF IP BELONGING TO FUZZY SET D

Criterion	"Weight" criterion (w_i)	α_i	Degrees of belonging to sets V^{α}				
			IP_1	IP_2	IP_3	IP_4	IP_5
NPV	0,438	2,189	0,072	0,029	0,327	0,458	0,219
IRR	0,252	1,259	0,526	0,418	0,418	0,220	0,316
PI	0,192	0,958	0,515	0,613	0,214	0,416	0,613
DPP	0,060	0,301	0,857	0,759	0,898	0,812	0,759
INV	0,059	0,293	0,901	0,703	0,765	0,937	0,901
Minimum			0,072	0,029	0,214	0,220	0,219

Thus, fuzzy set D has an appearance:
D = {IP1/0,072, IP2/0,029, IP3/0,214, IP4/0,220, IP5/0,219}.
The best IP can be determined from the condition:
μD(IP*) = max (0,072; 0,029; 0,214; 0,220; 0,219) = 0,220.
Since the maximum is for the fourth IP, we get the result: IP*= IP4.
Thus, taking into account the importance of the relevant requirements-criteria and requirements-restrictions for decision-makers, the result has changed: without taking into account the importance, the investment project IP5 was recognized as the most preferable, and given the importance, the investment project IP4 was the most preferable.

IV. CONCLUSION

In this article a formal tool for describing various requirements (requirements-criteria and requirements-limitations) for spatial development investment projects and means of their integration into a single model for assessing the effectiveness of investment projects at the pre-investment stage of the project life cycle is presented. A feature of spatial development investment projects is the fact that various requirements for them are formed based on the goals and interests of interested parties (stakeholders) – users, consumers, suppliers, developers and the business itself. Therefore, in general, the set of requirements includes both quantitative and qualitative requirements-criteria, along with requirements-restrictions. In order to obtain a comprehensive assessment of IP performance at the pre-investment stage, it is necessary to have a formal tool for describing various requirements and means for integrating them into a single assessment model. The result of such integration should be a single comprehensive assessment of IP performance, in which each private criterion used characterizes only a separate aspect of the implementation of the investment proposal. As a formal tool for describing various requirements, the mathematical apparatus of fuzzy set theory and the methodology of system analysis of hierarchical structures are used. The use of fuzzy set theory as an instrumental basis for describing various requirements is that it, although it does not eliminate the subjective nature of the concepts with which persons deal with the decision maker, but gives them the means to describe these subjective concepts in a rational way. The use of the proposed method of formalizing requirements and the formation of an assessment of the effectiveness of investment projects at the pre-investment stage of the life cycle it is demonstrated on a model example. At the same time, two cases were considered: the first case – requirements-criteria and requirements-restrictions have the same degree of importance for decision-makers and the second – requirements-criteria and requirements-restrictions have different degrees of importance for decision-makers. As the calculations showed, the priority (importance) of the corresponding requirements-criteria and requirements-restrictions for decision-makers is important for the assessment.

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REFERENCES

[1] E. Brigham, L. Gapenski, Financial management: Complete course, Economic school, vol. 1, St Petersburg, 2001.

[2] V.A. Kalugin, Multi-criteria methods of investment decision-making, Khimizdat, St Petersburg, 2004.

[3] V.V. Kovalev, Methods of assessment of investment projects, Finance and statistics, Moscow, 2000.

[4] D. Northcott, Making investment decisions, in: A. Shokhina (Eds.), Banks and Exchanges, UNITY, Moscow, 1997.

[5] B. Rębiasz, A. Macioł, “Comparison of Classical Multi-Criteria Decision-Making Methods with Fuzzy Rule-Based Methods on the Example of Investment Projects Evaluation”, in: R. Neves-Silva, L. Jain, R. Howlett (Eds.), Intelligent Decision Technologies, Smart Innovation, Systems and Technologies, vol. 39, Springer, Cham, 2015, pp. 549-561.

[6] I.M. Peshkhoev, I.V. Avlasenko, O.V. Panfilova, Y.V. Podkolzin, O.G. Savelyeva, “The Methods of Evaluation of Investment Project with Undetermined Parameters”, in: E. Popkova, V. Ostrovskaya (Eds.), Perspectives on the Use of New Information and Communication Technology (ICT) in the Modern Economy, vol. 726, Springer, Cham, 2019, pp. 64-71. DOI: https://doi.org/10.1007/978-3-319-90835-9_8

[7] V.A. Kalugin, “Rapid Investment Bid Evaluation”, Financial management, vol. 3, Moscow, 2006, pp. 73–85.

[8] T.L. Saaty, “A Scaling Method for Priorities in Hierarchical Structures”, Journal of Math Psychology, vol. 15, 1977, pp. 234–281. DOI: https://doi.org/10.1016/0022-2496(77)90033-5

[9] T.L. Saaty, Decision-making. Analytic hierarchy, Radio and communication, vol. 316, 1989.

[10] V.A. Kalugin, “Multi-Method Approach to Making Investment Decisions”, in: V.A. Kalugin, V.A. Lomazov, L.A. Zimakova, V.M. Nikitin, E.A. Lavrinenko (Eds.), International Business Management, vol. 10, 2016, pp. 6004–6008.

[11] E. Hull, K. Jackson, J. Dick, “Requirements Engineering”, Practitioner Series, 2nd edn. Springer, London, 2005, pp. 1–19. DOI: https://doi.org/10.1007/1-84628-075-3_1.

[12] L.A. Zadeh, “Fuzzy Sets”, Information and Control, vol. 8, 1965, pp. 338–353.

[13] R.R. Yager, “Multiple Objective Decision-Making Using Fuzzy Sets”, Intl. J. Man-Machine Studies, vol. 9, 1977, pp. 375–382.

[14] R.R. Yager, “A New Methodology for Ordinal Multi-Objective Decisions Based on Fuzzy Sets”, Decision Sciences, vol. 12, 1981, pp. 589–600.

[15] R.E. Bellman, L.A. Zadeh, “Decision Making in a Fuzzy Environment”, Management Science, vol. 17, 1970, pp. 141–16