MULTI CRITERION EFFICIENCY EVALUATION OF INVESTMENT PROJECTS PERFORMED IN UNCERTAINTY CONDITIONS

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Summary: The article presents a general outline of multi criterion evaluation method based on the use of fuzzy sets theory. The method proposed has been applied in the efficiency evaluation of investment projects executed in conditions of uncertainty. The investment projects evaluation is not an easy task in the context of their *ex ante* efficiency estimating, and in the multi criterion approach it becomes extremely complex. Another problem is proper formulation and aggregation of evaluation criteria. The criteria may be both of quantitative (financial indexes) and qualitative character (verbal evaluations). There may be many criteria, and in general, some of them have a much higher impact on the final evaluation than others. Multi criterion character of the decisions made is in this case related with a choice of an investment mostly preferred in view of the evaluation criteria assumed, whereas it is significant to determine the weight of individual criteria in relation to each other. The method of investment efficiency evaluation proposed, has been presented in an example of selection of one out of alternative financial investments.

Keywords: investment projects, efficiency evaluation, uncertainty, fuzzy sets theory.

1. Introduction

Investment has been one of the basic signs of the activity of enterprises for ages. Some of the enterprises invest in order to develop their activity, others, in order to continue it at an extent practised so far, or in order to adapt it to changing conditions in environment. An increase of the enterprise value is always a criterion for correctness of the decisions made. It is therefore obvious that the subject of the investment projects should be consistent with the strategy of the whole organization activity.

Success in the contracting business relies heavily upon selecting those investment options of most benefit to the organization in both the short and long term. Whether these benefits are purely monetary or a combination of monetary and non-monetary gains, investment options must be compared objectively.

Contracting organizations and developers tend to concentrate on establishing the financial viability of a project through feasibility studies. A project is deemed economically feasible, if the expected revenue meets or exceeds an acceptable pre-determined level of return on the organization's initial investment. As this procedure involves a degree of forecasting, decisions are frequently made based on past experience, either rationally or intuitively with some degree of uncertainty, and thus are made under risk [1]. If the total uncertainty is significant, as in the case of long term investments, not recognizing it will often totally distort the predictions, in an unknown way, making any decisions based on these predictions highly suspect. Therefore, it is paramount for an organization to be able to predict and compare all possible future monetary outcomes taking into account the inherent uncertainty associated with selected investment parameters including construction, operation and maintenance costs, interest rate, inflation, depreciation, tax rate, and operation life.

As a consequence, the basic question should be answered: is the execution of an investment project at the planned structure of its financing profitable? It seems then extremely necessary to evaluate the efficiency of the investment project.

The problem of efficiency of investment projects is a subject of analysis not only in numerous papers on management accounting, but also in papers on the theory of decision processes support. Hardly ever a full conformity of views is reached. The differences refer not only to the method of understanding, and as a consequence defining of the basic terms, but also to the method of preparation of procedures for the efficiency evaluation of investments projects [2, 3, 4].

2. Planning of investment efficiency

Planning of an investment project is understood as a selective method of data obtaining and processing, which facilitates making a correct decision regarding its execution or a withdrawal from it. The basic results of preparation and implementation of a project schedule should include: reduction of uncertainty, estimating of a probability of risks and chances (opportunities) appearance, and as a result reduction of a risk to make incorrect investment decisions.

A key feature of investment project planning involves not only determining of investment project efficiency evaluation methods , but mainly a comprehensive approach to the enterprise strategic situation. Such understanding of planning allows selection, out of many opportunities, of the ones which are mostly profitable, from the point of view of the organization.

Inspection functions in planning are not reduced to an inspection by external organizations; use of a feedback information is applied in an inspection of relation between the execution of individual stages of planned activities and their assumptions. The inspection involves correctness of plans, and works as a system of feedbacks between the objectives and their execution.

Efficiency, in accordance with commonly approved definition [5], is a result of activities made, described by a relation of effects obtained with outlays incurred. It refers to the best production, distribution, sale, promotion results. Efficiency of investment projects must be analysed within a long time span, resulting from the long period of fixed assets depreciation or from average depreciation rate of capital expenditures or from the time of repayment of a loan taken by the investor.

Efficiency may be identified in an *ex post* or an *ex ante* approach. If calculating of *ex ante* efficiency, the expected effects are estimated, at an engagement of specific resources and time. *Ex post* efficiency refers to determining of specific measures results. While it is relatively easy to determine the *ex post* efficiency, anticipating its *ex ante* value in the future is difficult and it additionally does not guarantee the investment success, which is related with a necessity of risk evaluation.

3. Project selection problem

Project selection is treated as a strategic decision problem undertaken by decision maker in an enterprise. The project selection is one of the first steps of managing projects [6].

The process of decision making in most cases consists in generating possible alternatives (alternative projects), evaluating these possibilities, and selecting the best variant (optimal project). The decision maker is responsible for making the final decision. In order to obtain the best decision the decision maker expresses preferences and defines selection criteria. He or she evaluates the solutions and approves final results [7]. This kind of problem is characterized by multiple, conflicting and incommensurate criteria [8]. The aim of decision maker is choose the best variant of project of the set of alternative project. Project selection is very complex decision making process. The project selection play significant role in the project management. It has great impact on the enterprise and its efficiency, competitiveness. The wrong decisions in project selection have their consequences. The cause of wrong decision is lost the benefits of the enterprises it could have gained if resources engaged in the project realization had been spent on more suitable project [9]. The enterprises should select and implement right project efficiently [10].

Project selection problem has been discussed by many researches. There is a large literature dedicated to the project selection. The main reason of the big interest of project selection is cause the project selection is a challenging issue especially for R&D and product development departments. The project selection can be applied in other similar areas, for example in logistics. This kind of problem includes several approaches with various aspects of the project selection. There are a lot of solutions methods. Project selection problem is supported by various computers program – based on decisions tools and methods.

Traditional project selection approaches focused on quantitative tools, such as discounted cash flow, net present value, return on investment and payback period [11].

Several authors have pointed out that the classical financial techniques (cannot be used to consider those benefits or costs that cannot be evaluated in monetary terms). These kind of project selection approaches ignore multiple factors (criteria) impacting the project selection. The traditional project selection approaches do not provide a useful transformative formula to combine all relevant factors (criteria) into a single decision making model [12]. For this reasons various “non-conventional” techniques have been proposed to solve the problem [13]. In practice it means that multiple-criteria scoring and ranking methods are used [14, 15]. The project selection research can be divided into two perspectives: solutions methods and fields of application [9]. Danila [14] presented R&D projects evaluation and selection methodologies and associated techniques. Meredith and Mantle [16] discussed various qualitative and quantitative methods for project selection.

4. Decisions in an investment process

An investment launching is a complex process, especially as far as investments are concerned which involve a lot of financial and time resources. An investor, before the decision is made on a starting up of such an investment, has to become familiar with various experts opinions and analyses, including a range of significant technical and economic assumptions related with the investment planned. The major ones include:

- investment objectives,
- planned expenditures necessary for the execution of the investment,
- extent and structure of the investment,
- criteria and methods used in investment efficiency evaluation,
- programme of works over the project,
- time of its implementing, execution.

Taking into consideration the assumptions above, the investor has to select rejection of a project and its acceptance. The problem is usually of a different rank, and it involves selection of the most efficient project, with the highest chances of success obtaining, or the best one, because of a different criterion assumption, out of several of projects presented. It is all brought down to decision making.

Investing, either in bonds or any financial instruments or development and innovative projects causes that the investor makes decisions in conditions of a particular risk. They refer to future – which cannot be anticipated in 100%. Efficiency of investment projects may reach in the future various values, with various probability assigned to them, which may depend on various factors. Some of the factors cannot be determined in any way, it is therefore not possible to include them in numerical analysis. In spite of many scales of measurement, available at the level of modern statistics, it is difficult for example to measure and include in analysis the political situation or, to a lesser extent – the economic situation in the world.

The basic question which therefore arises is – how to make a forecast, on the basis of various profit rates, so as to approach, at the highest level the status which may occur in the future. Determining of a return rate from investment, becomes the basis for investment decision making.

Decisions in an investment process are based on the following assumptions [17, 18]:

- investment decisions are made by independent businesses, guided exclusively by the economic criteria, investment decisions resulting from extra-economic reasons will therefore not be taken into consideration,
- investment decisions are made by businesses which already exist in economic environment and have specific resources; signs from the environment and the level of availability of resources determine and limit the scope of decisions made,
- investment decisions are taken on the basis of forecast data, which, by virtue of their nature, are charged with a certain error; the errors result both from erroneous assumptions regarding the situation in the future and the lack of proper concluding methods application - i.e. sensitivity analysis is a necessary element of evaluation.

5. Dynamic methods in evaluation of investment projects efficiency

A common feature of investment projects evaluation dynamic methods, otherwise referred to as discount methods, is that they take into consideration a variable value of money in time. Consequently, they require a proper selection of a discount rate r and generating of a forecasted cash flow during the investment time.

Proper application of discount methods requires becoming thoroughly familiar with their assumptions. The paper will further include a presentation of the properties of most frequently applied discount methods [19, 20] such as:

- net present value (NPV),
- profitability index (PI),
- internal rate of return (IRR),
- discount payback period (DPP).

Net present value (NPV) has been defined as a sum of discounted net cash flow (NCF), separately for every year, within the calculation period, at constant level of percentage (discount) rate.

The value represents an updated value of profit, for the day of the evaluation, which may be reached by the investment under analysis.

Tab. 1. Decision rules in NPV method

The project should be accepted when:		The project should be rejected when:
NPV>0	**NPV=0**	**NPV<0**
Project percentage profit rate is:		
Higher than the limit rate	Equal with the limit rate	Lower than the limit rate

If a choice is made between variants, the one for which NPV reaches the highest level should be selected.

Internal rate of return (IRR), is a percentage rate at which the current (updated) value of money expenditures streams is equal with the current value of the money revenue streams. It is therefore a percentage rate at which an updated net value of the investment subject to evaluation equals zero (NPV=0).

IRR directly reveals the return rate of the investments under research. Single investment is profitable if its inner return rate is higher than the limit rate (in extreme cases equal with), being the lowest possible profit rate to be accepted by the investor.

Profitability index (PI) also referred to as the yield index, is a quotient of the total discounted positive cash flow with the total discounted negative cash flow.

Investment project is assumed for execution at level PI>1. The basis for selection of the most profitable out of the investment projects taken for analysis is a maximizing of the PI value. The higher the value of the index, the more profitable project can be therefore expected. The index is used in practice in a situation when a potential investor has got limited financial resources. It is also obvious that the index may be counted only for investment projects with a positive NPV value, since a negative updated net value immediately eliminates an investment project.

Discount payback period (DPP) of the expenditures incurred due to investment execution, informs about time necessary in order that the accumulated cash flow generated by the investment reaches the zero value, i.e. the money revenue covers the investment outlays.

6. Multi criterion efficiency evaluation of investment based on the application of fuzzy sets theory

To evaluate the project execution plans, a method was used, based on use of fuzzy sets theory [21]. The evaluation is of a multi criterion character [22], and is convergent with the general evaluation methodology (Fig. 1), including at the same time the non-equivalency and variability of criteria, their hierarchy and uncertainty of the experts' evaluations.

Using fuzzy sets theory, criteria indexes become transformed into fuzzy form of partial variant evaluations by means of transformation functions. The method facilitates comparison of different values by their transformation into fuzzy numbers within the interval of $\langle 0, 1\rangle$. Application and the three-stages implementing of the method have been presented in the next example.

Basic input data in the multi criterion evaluation method include a number of investments projects variants a_i, i=1, ..., n, where $a_i \in \langle 3; 10\rangle$ (in accordance with the assumptions of the method). In the case under analysis a_i=4 and in the stage of pre-selection it forms a set of alternative investments, which are possible to be started {Project 1, ..., Project 4}.

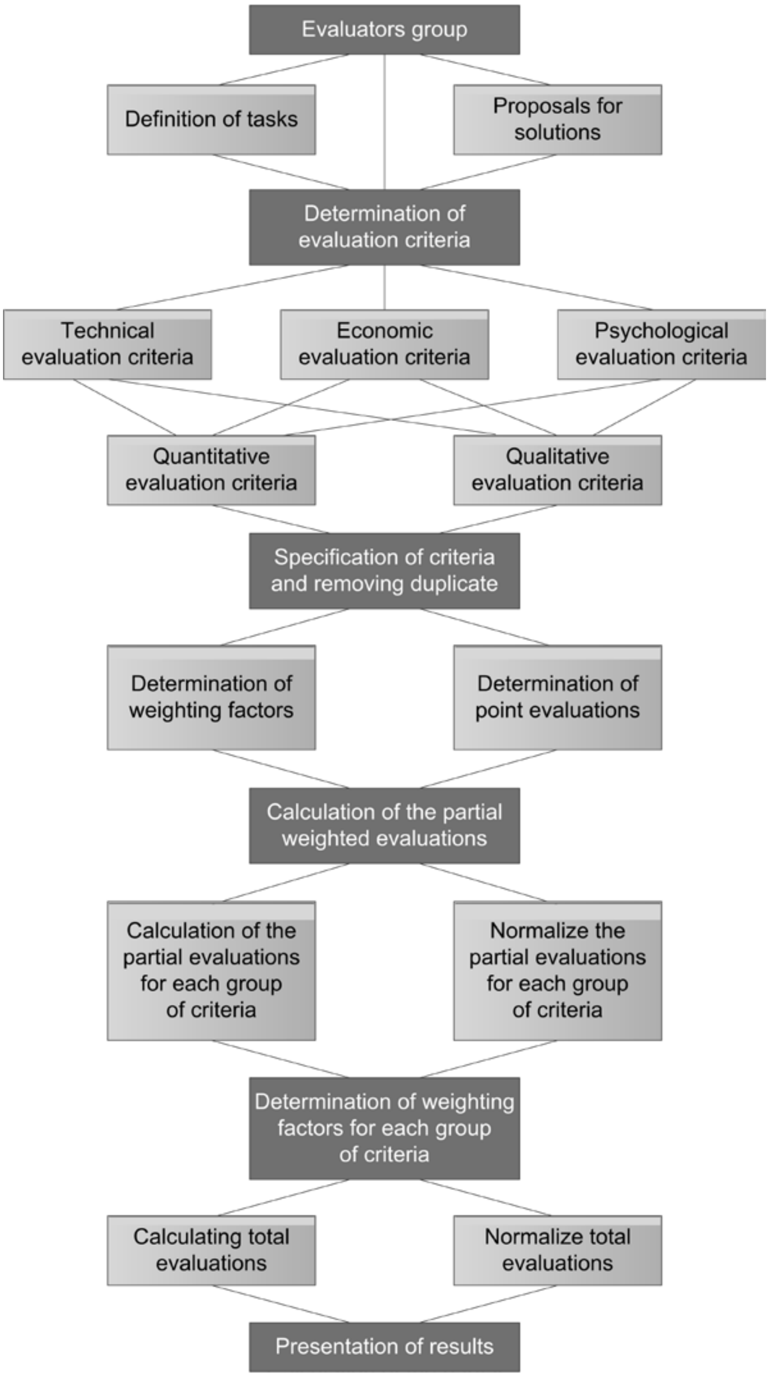

Fig. 1. General evaluation methodology (own elaboration based on [21])

Another input data include a number of criteria k_j, j=1, ..., m (in this case k_j=5) and their set of {K1, ..., K5}. Selection of final evaluation criteria depends on the main expert and is specified immediately at the beginning of the evaluation of possible variants of project execution plan.

The chief expert has indicated the following evaluation criteria in evaluation of investment projects efficiency (selected discount methods for typical projects, with risk):

K1: IRR – internal rate of return,

K2: NPV – net present value,

K3: PI – profitability index,

K4: DPP – discount payback period,

K5: R – risk.

List of criteria indexes for individual variants of investments planned has been included in table 2.

Tab. 2. Criterion indexes for the evaluated investment projects

	IRR	NPV	PI	DPP	R
Project 1	27,92%	276,8	1,14	41	0,25
Project 2	42,83%	435,2	1,45	48	0,6
Project 3	34,56%	399,6	1,23	24	0,3
Project 4	38,91%	310,7	1,32	36	0,5

Determining of the value of individual criteria is based on calculating of weights, of a fuzzy character. Criteria weights, in fuzzy approach, have been represented by a fuzzy set with assignment function w_j. Assignment functions formed have been represented within the interval $\langle 0, 1 \rangle$, and the range has been determined as the basic space.

Qualitative criteria importance is determined by means of linguistic terms. This way of criteria importance determination requires adopting one common criterion treated as important (in the analyzed example is the risk – R) by all experts and determining common criteria sets treated as more and less important. The importance of criteria in both sets may be expressed by the experts individually.

Determinist variant evaluations have been determined in various dimensions depending on the criterion and assumed value scale. The evaluations values have been transformed by means of typical transformation functions according to function no. 1 (also possible to use functions no. 4 and no. 5) for criteria IRR, NPV, PI, and function no. 2 (possible function no. 3 and no. 6) for criteria DPP, R into the interval $\langle 0, 1 \rangle$ (Fig. 2).

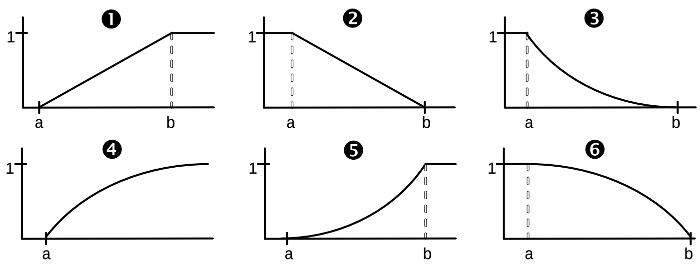

Fig. 2. Transformation functions for project variants evaluations

The evaluation of variants for the criteria K1, K2, K3 (IRR, NPV, PI) has been modeled transformation function no. 1, according to the following ranges:

(-∞,a⟩ – unacceptable internal rate of return/net present value/profitability index,

(a,b) – allowable internal rate of return/net present value/profitability index,

⟨b,+∞⟩ – optimal internal rate of return/net present value/profitability index.

The function no. 2 transforms the value of evaluation due to the criteria K4, K5 (DPP, R) adopted the following form:

⟨0,a⟩ – optimal discount payback period/risk,

(a,b) – allowable discount payback period/risk,

⟨b,+∞) – unacceptable discount payback period/risk.

Table no. 3 presents a list of criteria with weights assigned to them, in a form of linguistic evaluation for each of three experts, and partial evaluations of the variants, in form of triangular assignment functions.

Tab. 3. Criteria weights evaluation and partial variants evaluations

CRITERIA WEIGHTS EVALUATION
linguistic

The list of criteria

K 1:	Criterion IRR
K 2:	Criterion NPV
K 3:	Criterion PI
K 4:	Criterion DPP
K 5:	Criterion R

Expert	Criterion	Evaluation	Function
Expert1	K 1:	the most important	function 1
	K 2:	the least important	function 6a
	K 3:	a little less important	function 4
	K 4:	a little more important	function 3
	K 5:	important	
Expert2	K 1:	the most important	function 1a
	K 2:	the least important	function 6
	K 3:	less important	function 5a
	K 4:	very important	function 2
	K 5:	important	
Expert3	K 1:	very important	function 2
	K 2:	less important	function 5
	K 3:	the least important	function 6
	K 4:	the most important	function 1
	K 5:	important	

PARTIAL VARIANTS EVALUATIONS
as triangular assignment functions

Criterion	Variant				
Criterion IRR	V 1:	0.0000	0.0000	0.2000	T.2
	V 2:	0.3127	0.8000	1.0000	T.1
	V 3:	0.1605	0.2178	0.4800	T.1
	V 4:	0.2592	0.6400	0.6800	T.1
Criterion NPV	V 1:	0.0000	0.0000	0.0400	T.2
	V 2:	0.3486	0.6400	1.0000	T.1
	V 3:	0.3103	0.5184	0.8667	T.1
	V 4:	0.1331	0.1600	0.3333	T.1
Criterion PI	V 1:	0.0000	0.1426	0.4000	T.1
	V 2:	0.3193	0.7000	1.0000	T.1
	V 3:	0.1111	0.2061	0.5000	T.1
	V 4:	0.2649	0.4444	0.6000	T.1
Criterion DPP	V 1:	0.9143	1.0000	1.0000	T.3
	V 2:	0.0571	0.1211	0.5353	T.1
	V 3:	0.7429	0.8825	0.9648	T.1
	V 4:	0.4000	0.6836	0.6873	T.1
Criterion R	V 1:	0.9000	0.9722	1.0000	T.1
	V 2:	0.0000	0.2000	0.5580	T.1
	V 3:	0.8000	0.8889	0.9200	T.1
	V 4:	0.0000	0.4000	0.6592	T.1

In order to obtain total fuzzy evaluation of the variant Z_i, the partial evaluations of variants B_{im}, and the w_m criteria weights coefficients are subject to aggregation:

$$Z_i = F(B_{i1}, B_{i2},..., B_{im}, w_1, w_2,...., w_m), \quad i=1, ..., n; \quad j=1 ,.., m; \tag{1}$$

where: Z_i – fuzzy set determined at interval ⟨0, 1⟩,

F – aggregation function, in particular cases linear function,

n – number of variants of the investments planned,

m – number of criteria assumed for the evaluation of individual variants.

Interpretation of results obtained in the aggregation process is related with the analysis of assignment function values modelling the total evaluation of individual investment project variants. Every set Z_i, i=1 ,..., n is transformed for interval $\langle 0, 1 \rangle$, but value $Z_i(z)$ determines the degree to which the value is in agreement with the i-th variant evaluation treated as the most preferable.

Evaluations of variants of the investments planned in form of assignment functions, for the example analysed in the article, have been presented in figure 3.

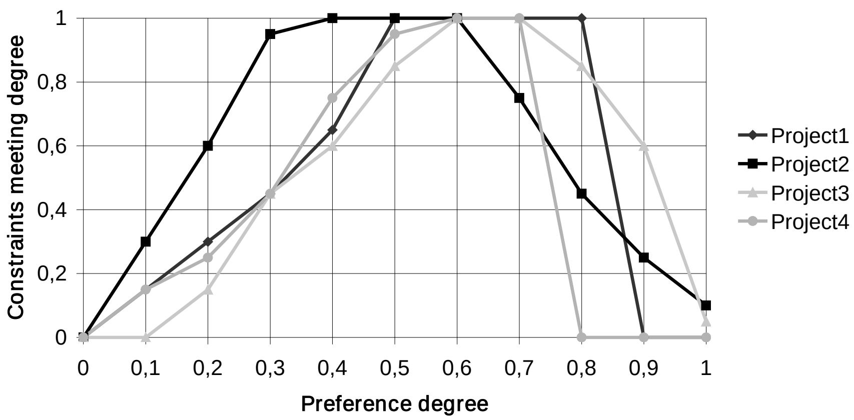

Fig. 3. Investment project variants evaluations in form of assignment functions

To formally determine the preference degree of individual variants it is necessary to order all fuzzy sets Z_1, Z_2, ..., Z_n, where e.g. $Z_i \prec Z_j$ means, that j-th variant is preferred from i-th variant.

P_i investment project final evaluations obtained after transformation of fuzzy values to real numbers space g: $Z_i \rightarrow R$ by means of transformation (2), have been presented in table 4.

$$Z_i \rightarrow P_i = \frac{\int_0^1 z \cdot Z_i(z)dz}{\int_0^1 Z_i(z)dz} \tag{2}$$

where: i-th variant is preferred with regard to the j-th if the condition $P_i > P_j$, and P_i, $P_j \in \langle 0, 1 \rangle$ occurs.

Tab. 4. Investment project final evaluations obtained for the analysed example

	Evaluation	Normalized evaluation
Project 1	0,6307	0,9647
Project 2	0,4761	0,7282
Project 3	0,6537	1,0000
Project 4	0,5713	0,8739

The method described included also measures of relations between variants, which gives a possibility to preserve information on the existing structure between individual evaluations. Parameters representing relations between variants are:

- relation β_{ij} degree, also called sets Z_i, Z_j interaction index – reflects the sets overlapping:

$$\beta_{ij} = \int_0^1 (Z_i \cap Z_j)(z)dz = \int_0^1 \min[Z_i(z), Z_j(z)]dz\ ; \tag{3}$$

- Z_i, Z_j fuzzy sets Ψ_{ij} evaluations identity degree – depends proportionally from their respective β_{ij} interaction index, which means, that with the relation degree increase, the identity degree of evaluations expressed by them (Fig. 4) also increases, which works the opposite way round as well.

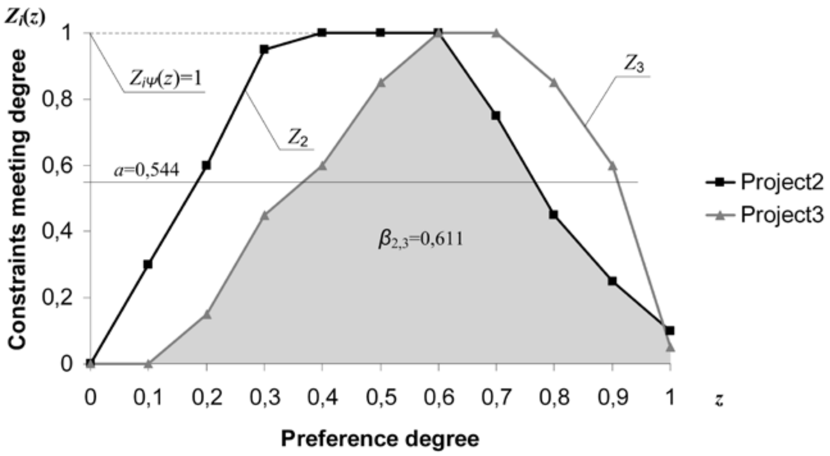

Fig. 4. Investment project variants Project 2 and Project 3 evaluations as assignment functions, with indicated interaction index $\beta_{2,3}$ of fuzzy sets Z_2, Z_3

Sets $Z_1, Z_2, ..., Z_n$ obtained as a result of aggregation may be characterized by an excessive, unnecessary in the aspect of interpretation fuzziness, especially for the function values $Z_i(z)$ close to zero. Constraint of the undesirable fuzziness impact, disturbing assignment functions analysis results, may be obtained by adopting an appropriate precision index; the functions shall not be interpreted below the index.

Investment project variants final evaluations in the example was obtained taking into account information precision index (a = 0,544).

Project 3 obtained the best final evaluation in the example under analysis. The project has been, as a consequence, accepted as a proper one, for starting the investment planned.

7. Concluding remarks

The estimation of values of investment parameters is undoubtedly crucial to the success of the feasibility study. As a result, the study must be detailed enough to allow major risk factors to be identified and critically assessed. It is not uncommon for organizations to commit considerable financial and human resources towards project appraisal. For example, the EuroTunnel project promoters spent approximately $1 million US dollars on the feasibility study before the tender was even won [23].

Traditionally, the net present value, internal rate of return and payback period investment appraisal techniques have formed the major component of feasibility studies. These three techniques are based upon the time-cost-of-money principle and use slightly varied procedures to forecast the expected monetary returns on an investment. The reliability of their output depends upon the accuracy of the deterministic cash flow values (benefits and costs), and their timing, as estimated by the organization. A fundamental limitation of this assumption is that the various investment parameters cannot be practically assumed with a higher degree of certainty. The value of each parameter is affected by a myriad of risks and uncertainties which are often difficult to quantify. An element of uncertainty lies with each prediction which, alone or in combination, may have a significant impact on the outcome of the economic analysis. Uncertainty, emanating from the project itself or external factors, will always be present and needs to be accurately captured in the decision-making process [24].

Evaluation of investments projects is a task of particularly complex character. The main sources of the problem complexity include among others: acting in conditions of uncertainty, multi criterion and multi level decision making.

The method of multi criterion evaluation presented in the paper, based on use of the fuzzy sets theory, applied in the evaluation of investment projects efficiency in the conditions of uncertainty, constitutes a universal method. It provides support for decision makers in making decisions in various domains, practically in all cases in which evaluation criteria set is possible to be determined. It moreover includes non-equivalency and variability of criteria, their hierarchy and uncertainty of the experts evaluations, while efficient and relatively simple in implementing at actual decision problems.

References

1. Moselhi O., Deb B.: Project selection considering risk. Construction Management and Economics, 11, 1993, pp. 45-52.
2. Skrzypek J.: Ocena opłacalności inwestycji. Materiały szkoleniowe. Kraków, 2005.
3. Guseva M. V., Demidova L. A.: Multicriterial classification of investment projects using fuzzy inference systems and multisets. Automatic Documentation and Mathematical Linguistics, Vol. 41, No. 1, 2007, pp. 23-27.
4. Pisz I., Mach Ł.: Wielokryterialna ocena opłacalności inwestycji [w:] Programowanie rozwoju regionu. Instrumentarium rozwoju. Ład społeczny. Pod redakcją naukową Krzysztofa Malika. Wydawnictwo Instytutu Śląskiego, Opole, 2007, pp. 115-126.
5. Adamczyk J.: Efektywność przedsiębiorstw sprywatyzowanych. AE, Kraków, 1995, pp. 33-36.
6. Laha D., Mandal P. (eds.): Handbook of computational intelligence in manufacturing and production management. IGI Global, New York, 2008.
7. Sawicka H., Żak J.: Total Logistic Management. 3, 2010, pp. 65-77.
8. Liesiö J., Mild P., & Capros P.: Preference programming for robust portfolio modeling and project selection. European Journal of Operational Research, 181, 2007, pp. 1488-1505.

9. Shakhsi-Niaei M., Torabi S.A., Iranmenesh S.H.: A comprehensive framework for project selection problem under uncertainty and real-world constraints. Computers & Industrial Engineering, 61, 2011, pp. 226-237.
10. Dey P.K.: Integrated project evaluation and selection using multi-attribute decision-making technique. International Journal of Production Economics, 103, 2006, pp. 90-103.
11. Liberatore M.J.: An extension of the analytic hierarchy process for industrial R&D project selection and resource allocation. IEEE Transactions on Engineering Management, 34, 1, 1987, pp. 12-18.
12. Brewer P.C., Gatian A.W., Reeve J.M.: Management uncertainty. Management Accounting, 75, 1993, pp. 39-45.
13. Enea M., Piazza T.: Project selection by constrained fuzzy AHP. Fuzzy Optimization and Decision Making, 3, 2004, pp. 39–62.
14. Danila N.: Strategic evaluation and solution of R&D projects. R&D Management, 19, 1989, pp. 47-62.
15. Chiadomrog N.: An integrated fuzzy multi-criteria decision making method for manufacturing strategies selection. Computers & Industrial Engineering, 37, 1-2, 1999, pp. 433-436.
16. Meredith J.R., Mantle S.J.: Project management: a managerial approach. Wiley, New York, 2000.
17. Skrzypek J. (red.): Projekty współfinansowane ze źródeł UE. Praca zbiorowa. Twigger, Warszawa, 2005.
18. Filar E., Skrzypek J.: Biznesplan. Poltext, Warszawa, 2005.
19. Pawlak Z.: Biznes plan. Zastosowania i przykłady. Poltext, Warszawa, 2005.
20. Rogowski W.: Rachunek efektywności przedsięwzięć inwestycyjnych. Oficyna Ekonomiczna, Kraków, 2004.
21. Breiing A., Knosala R.: Bewerten technischer Systeme. Springer Verlag, Berlin, 1997.
22. Łapuńka I.: Modelowanie rozmyte wielokryterialnej oceny harmonogramu realizacji projektu. Gospodarka Materiałowa i Logistyka, 11/2011, pp. 39-42.
23. Levy S.M.: Build, operate, transfer: paving the way for tomorrow's infrastructure. Wiley, Canada, 1996.
24. Mohamed S., McCowan A.K.: Modelling project investment decisions under uncertainty using possibility theory. International Journal of Project Management, 19, 2001, pp. 231-241.

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