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ESTIMATION OF INPUT FINANCIAL AND ECONOMIC PARAMETERS OF AN INVESTMENT PROJECT BASED ON A FUZZY SET APPROACH*

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Estimation of Input Financial and Economic Parameters of an Investment Project Based on a Fuzzy Set Approach

The article considers the problem of estimating input financial and economic parameters of investment projects in the form of fuzzy quantities (numbers). The results of the study give grounds to state that the modern fuzzy set methodology comprises a sufficiently developed arsenal of methods for constructing the membership functions of fuzzy sets, some of which can be used for carrying out economic analysis and evaluating real investment. At the same time, the issue of estimating input financial and economic parameters of investment projects has its own peculiarities, thus when addressing it, the turning to general approaches should be complemented with elaborating and developing special methods. Such special methods, in particular, are the method based on quasi-statistics and the method of reference points. The paper proposes an approach to finding fuzzy estimates of the input financial and economic parameters of real investments, which, in accordance with its logic, was called the method of reference intervals. The constructive principle of this method is to represent a sought-for fuzzy estimate using the interval approximations of its core and carrier. The specified interval approximations, which are interpreted as reference intervals, are determined on the basis of the principles of the theory of rough sets. A promising direction of further scientific research on the issues touched upon in the publication is the development of a methodological apparatus for considering the combined uncertainty in the structure of input data when modeling economic efficiency of real investment.

Keywords: *investment project, uncertainty, fuzzy set theory, membership function, fuzzy number, theory of rough sets.*

Fig.: *1.* ***Formulae:*** *7.* ***Bibl.:*** *17.*

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Коцюба О. С. Оцінювання початкових фінансово-економічних параметрів інвестиційного проекту на основі нечітко-множинного підходу

Статтю присвячено проблемі оцінювання початкових фінансово-економічних параметрів інвестиційних проектів у формі нечітких величин (чисел). Результати проведеного дослідження дають підстави констатувати, що сучасна нечітко-множинна методологія містить у своєму складі достатньо розвинений арсенал методів побудови функцій належності нечітких множин, певна частина яких припускає використання для економічного аналізу та оцінки реальних інвестицій. Водночас питання оцінювання початкових фінансово-економічних параметрів інвестиційних проектів має свої особливості, внаслідок чого стосовно нього звернення до загальних підходів має доповнюватися розробленням і розвитком спеціальних методів. Такими спеціальними методами, зокрема, є метод на основі квазістатистики, а також метод опорних точок. В роботі було запропоновано підхід до знаходження нечітких оцінок вихідних фінансово-економічних параметрів реальних інвестицій, названий відповідно до його логіки методом

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Коцюба А. С. Оценка начальных финансово-экономических параметров инвестиционного проекта на основе нечетко-множественного подхода

Статья посвящена проблеме оценки начальных финансово-экономических параметров инвестиционных проектов в форме нечетких величин (чисел). Результаты проведенного исследования дают основания констатировать, что современная нечетко-множественная методология содержит в своем составе достаточно развитый арсенал методов построения функций принадлежности нечетких множеств, определенная часть которых допускает использование для экономического анализа и оценки реальных инвестиций. В то же время вопрос оценки начальных финансово-экономических параметров инвестиционных проектов имеет свои особенности, вследствие чего относительно него обращение к общим подходам должно дополняться разработкой и развитием специальных методов. Такими специальными методами, в частности, является метод на основе квазистатистики, а также метод опорных точек. В работе был предложен подход к нахождению нечетких оценок исходных финансово-экономических

* *Стаття підготовлена згідно з планами наукових досліджень кафедри стратегії бізнесу Київського національного економічного університету ім. В. Гетьмана за темою "Стратегічне управління розвитком підприємницьких структур" (державний реєстраційний номер 0116U001430).*

опорних інтервалів. Конструктивний принцип цього методу полягає у відтворенні шуканої нечіткої оцінки за допомогою інтервальних наближень її ядра і носія. Зазначені інтервальні наближення, які інтерпретуються як опорні інтервали, визначаються на основі ідей теорії грубих множин. Актуальним напрямом дальших наукових пошуків за порушеною в публікації проблематикою є розвиток методичного апарату для врахування комбінованої (неоднорідної) невизначеності в структурі вихідних даних при моделюванні економічної ефективності реальних інвестицій.

Ключові слова: *інвестиційний проект, невизначеність, теорія нечітких множин, функція належності, нечітке число, теорія грубих множин.*

Рис.: *1.* ***Формул:*** *7.* ***Бібл.:*** *17.*

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параметров реальных инвестиций, названный в соответствии с его логикой методом опорных интервалов. Конструктивный принцип данного метода заключается в воспроизведении искомой нечеткой оценки с помощью интервальных приближений ее ядра и носителя. Указанные интервальные приближения, которые интерпретируются как опорные интервалы, определяются на основе идей теории грубых множеств. Актуальным направлением дальнейших научных поисков по затронутой в публикации проблематике является развитие методического аппарата для учета комбинированной неопределенности в структуре исходных данных при моделировании экономической эффективности реальных инвестиций.

Ключевые слова: *инвестиционный проект, неопределенность, теория нечетких множеств, функция принадлежности, нечеткое число, теория грубых множеств.*

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Introduction. Success of investment activities of an enterprise largely depends on the justification of investment decisions made, whereas a fundamental factor destabilizing the evaluation of economic efficiency of investment projects is uncertainty. Hence, high-quality analytical support for real investment processes suggests taking into account uncertainty, using and forming an arsenal of relevant analytical tools.

In the structure of modern investment analysis and investment management, issues associated with consideration of uncertainty in making decisions on real investment occupy one of the central places. A clear example of this is their wide representation in the educational and monographic literature in the relevant field, in particular, in the works of H. Bierman, S. Smidt, U. Götze, J. Bloech, A. Damodaran, P. P. Peterson, F. J. Fabozzi, S. Goel, R. Tiffin, J. Gil-Aluja, and others [1–7].

As is demonstrated by the results of studying these and other works, in which the outlined problematic is highlighted, the basic mathematical theories that are now proposed to model uncertainty at economic justification of investment projects are probability theory, the theory of subjective probabilities, interval analysis, and the fuzzy set theory. It should be noted that the latter is a new approach, which served as the basis for developing methods and models that are used in practice. At the same time, the creation in the framework of this approach of a comprehensive and internally coordinated methodological apparatus to solve problems of investment analysis is still far from complete and requires further research.

One of the key issues in applying the fuzzy set theory to analyze and evaluate economic efficiency of real investment is a justified estimation of input financial and economic parameters of an investment project under consideration. Although it has been an object of attention of scientists for quite a long time, the results obtained demonstrate that not all possible approaches were used to solve it yet. Thus, it is a further consideration of this issue that is set as the objective of the proposed study.

Presentation of basic material of the research. The essence of the problem of estimating input financial and economic parameters of an investment project based on the fuzzy set method is characterized as follows.

Estimates of the analyzed parameters are interpreted either as fuzzy quantities, i.e., random fuzzy sets defined over a set of real numbers, or as fuzzy numbers presented by fuzzy quantities of a special type [8, p. 137-139]. Hence, a fuzzy set estimation of financial and economic parameters of an investment project is reduced to defining the membership functions of the corresponding fuzzy quantities or numbers.

In the framework of the fuzzy set methodology, a comprehensive methodological apparatus to construct the membership functions of fuzzy sets was developed [9, p. 259–276; 10, p. 7–30]. The main differences of various methods are associated with the fact of whether membership functions are defined directly or indirectly and whether one or several experts take part in evaluating them.

The direct method implies defining a membership function either by directly assigning degrees of membership to individual values of a characteristic (object) under study, or by using an analytical expression (formula). In the case of applying indirect methods, the values of a membership function are found based on realizing for them the predetermined conditions. One of the popular methods of this group is the method of pairwise (paired) comparisons (another name used: the eigenvalue method), which was developed by T. L. Saaty [11]. It should be noted that due to the universality of its conceptual scheme, the mentioned method can be applied for solving various practical problems, evaluation of the membership function of a fuzzy set being only one of them.

Both the method of pairwise comparisons and other methods developed in the framework of the general theory of constructing membership functions can be successfully used in investment analysis. At the same time, the problematics of fuzzy set modeling of input financial and economic parameters of investment projects has its own characteristics, which is why when considering it turning to general approaches should be complemented by the development and use of special methods.

The above considerations are supported by the results of the review of various scientific works highlighting economic analysis of real investment by means of the theory of fuzzy sets, which, on the one hand, did not allow to find out some coherent special methodology for fuzzy set estimation of input data of investment projects, and on the other hand, made it possible to reveal the main current trends concerning this issue.

First, a starting point in studies of various authors is the consideration of an arsenal of methods for constructing the membership functions of fuzzy sets, which are intended for the most diverse areas of possible application, including those that can be used in solving problems of investment analysis (see, for example, [14]).

Secondly, special attention is paid to the elaboration and development of methods for which the problem of economic evaluation of real investment is considered as one of priorities. An example of a method of this kind is fuzzy set modeling of input financial and economic parameters of investment projects based on statistical data. The latest results in the development of its theoretical and methodological aspects are obtained by A. O. Nedosekin. In particular, the researcher proposed the concept of quasi-statistics, which in a concentrated form describes the situation of a legitimate or effective application of this approach.

According to [12, p. 45-46], "quasi-statistics is a sampling from the general set of observations considered to be insufficient for identification of probabilistic law of distribution with precise parameters, but is sufficient to prove to some subjective extent of authenticity the law of observation in probabilistic or any other form, and the parameters of this law will be set by special rules to meet the required authenticity of identification of the law of observation". Developing his ideas on the theoretical construction of quasi-statistics, A. O. Nedosekin also notes [12, p. 46]: "Strictly speaking, without postulating quasi-statistics, it is impossible to create scientifically proven models of non-uniform and observation-limited processes of the stock market and the economy as a whole, it is impossible to take into account the uncertainty accompanying the process of making financial decisions".

Another method used to obtain membership functions for quantitative estimations, which has become widespread in fuzzy set modeling of real investment, is to represent them on the basis of several values (points), when, first, the degrees of membership for individual values in the framework of estimating the parameter under study is specified to some extent, and then the entire sought-for estimate, which is assumed as a continuous fuzzy quantity (number), is presented [12; 13; 14]. In the case of investment analysis, the latter is implemented, as a rule, using standard types of fuzzy numbers – rectangular (interval), triangular, trapezoidal, Gaussian, etc. In view of the logic of the outlined approach, it is correct and convenient to call it the method of reference values (points).

In general, the results of the review suggest prospects for further development of tools to solve the problems under study based on complementing or strengthening the potential of formalisms of the theory of fuzzy sets with ideas of other approaches to analyzing and modeling uncertainty, in particular, the theory of rough sets. First of all, let us present some basic information about the latter one [15].

The theory of rough sets was proposed in the early 1980s by a Polish scientist Z. Pawlak [16]. Its core is formed by the concept of rough set, which is based on the concepts of the so-called lower and upper approximation of a set. The ideas and approaches of this theory turned out to be productive for data mining, as well as many other applied problems in various spheres. In its essence, the theory of rough sets complements other approaches used when working with fuzzy information.

Let U be a universal set (the universe), X – its certain subset $(X \subseteq U)$, $R \subseteq X \times X$ – an equivalence relation (within the considered theory it is interpreted as indiscernibility relation), $[x]_R$ – the equivalence class of the element x relative to R (in the rough set theory each equivalence class induced by the relation R is called an elementary set). Then, according to the described approach, each set can be represented by two sets – R-lower ($\underline{R}X$) and R-upper ($\overline{R}X$) approximation:

$$\underline{R}X = \{x \mid [x]_R \subseteq X\}, \quad (1)$$

$$\overline{R}X = \{x \mid [x]_R \cap X \neq \varnothing\}, \quad (2)$$

whence it follows that

$$\underline{R}X \subseteq X \subseteq \overline{R}X. \quad (3)$$

That is R-lower approximation includes elements that surely belong to the set X, whereas R-upper approximation includes elements that possibly belong to the set X.

Based on the presented pair approximations, the universe U can be broken down into three subsets:

$POS_R(X) = \underline{R}X$ – R-positive region, elements of which, according to the definition of R- lower approximation, surely belong to the set X;

$NEG_R(X) = U \setminus \overline{R}X$ – R-negative region, elements of which surely do not belong to the set X;

$BN_R(X) = \overline{R}X \setminus \underline{R}X$ – R-borderline region, elements of which belong to R- upper approximation and do not belong to R-lower approximation.

The analysis of the logical scheme on which the concept of rough set is based allows to notice the possibility for using it to model input financial and economic parameters of real investment in situations with a high degree of uncertainty, when an expert, based on the availability of actual data or their lack, as well as knowledge, experience and intuition, finds it difficult to evaluate particular parameters using a probabilistic methodology (including the theory of subjective probabilities), as well as a few fuzzy methods discussed above.

Let X be a certain input financial and economic parameter of the investment project, the value of which is to be estimated. We will further assume that the estimate of this parameter is a fuzzy number. Let us denote it by $\tilde{X}$. According to the approaches proposed by us, obtaining the sought-for fuzzy estimate involves the following steps.

The expert determines the interval of values of the studied financial and economic parameter, which, in his opinion, can be realized from purely theoretical point of view. We call this interval an inner reference one. Technically this step can be done as follows.

A certain initial value that meets the above condition is set. It is assigned the status of a reference one (the basis). Gradually moving to the left and right of the basis, new values are added to it. The process continues until the expert faces the difficulty in trying to go further.

The inner reference interval assumes the interpretation as the outer approximation of the core and an inner approximation of the support for the sought-for fuzzy estimate. Let us recall the definition of the notions of the support and the core of a fuzzy set.

The support of a fuzzy set is the crisp set that contains only those elements of the universal set (the universe) for which the values of the membership function of this fuzzy set are nonzero.

The core of a fuzzy set is the crisp subset of its elements for which the values of its membership function are equal to 1.

Thus, in view of the foregoing

$$\underline{x}^{*} \le \underline{x}^{1} \le \overline{x}^{1} \le \overline{x}^{*}, \qquad (4)$$

$$\underline{x}^{0} \le \underline{x}^{*} < \overline{x}^{*} \le \overline{x}^{0}, \qquad (5)$$

where $[\underline{x}^{*}, \overline{x}^{*}] = \overline{\overline{X}}^{*}$ is the inner reference interval for constructing the fuzzy estimate of the parameter X;

$\underline{x}^{*}$, $\overline{x}^{*}$, are respectively the lower and upper bound of the inner reference interval $\overline{\overline{X}}^{*}$;

$[\underline{x}^{1}, \overline{x}^{1}] = \overline{\overline{X}}^{1}$ is the core of the fuzzy number $\tilde{X}$;

$\underline{x}^{1}$, $\overline{x}^{1}$, are respectively the lower and upper bound of the interval that defines the core of the fuzzy number $\tilde{X}$.

$[\underline{x}^{0}, \overline{x}^{0}] = \overline{\overline{X}}^{0}$ is the closure of the support of the fuzzy number $\tilde{X}$;

$\underline{x}^{0}$, $\overline{x}^{0}$, – are respectively the lower and upper bound of the interval that represent the closure of the support of the fuzzy number $\tilde{X}$.

To the left and to the right of the interval obtained in the previous step, the expert determines semi-infinite intervals of values of the analyzed financial and economic parameter, which, in his opinion, cannot be realized at all. We call them respectively the lower non-reference and upper non-reference intervals. For example, in the case of a lower non-reference interval, this can be done in the following way.

To the left of the inner reference interval, a certain input value is set, which corresponds to the condition specified above. It is assigned the status of a reference one (the basis). Gradually moving to the right of the basis, new values are added to it. The process continues until the expert faces the difficulty in trying to go further. The constructing of the upper non-reference interval is carried out similarly to that of the lower non-reference one.

Let us introduce the following denotations for a formalized description of the presented theoretical constructs:

$\overline{\overline{X}}^{(-)} = (-\infty, \overline{x}^{(-)}]$, $\overline{\overline{X}}^{(+)} = [\underline{x}^{(+)}, +\infty)$, are respectively the lower non-reference and upper non-reference interval in relation to the fuzzy estimate of the parameter X;

$\overline{x}^{(-)}$ is the upper bound of the non-reference interval;

$\underline{x}^{(+)}$ is the lower bound of the non-reference interval.

There determined the interval of values of the analyzed financial and economic parameter, which contains: firstly, the inner reference interval; secondly, the values with which the expert experienced difficulties when trying to assign them to the inner reference interval and non-reference intervals, as well as the bounds of the latter ones – $\overline{x}^{(-)}$ and $\underline{x}^{(+)}$. Let us call this interval the outer reference one. The formula for finding the outer reference interval can be written as follows:

$$\overline{\overline{X}}^{**} = [\underline{x}^{**}, \overline{x}^{**}] = \{\overline{x}^{(-)}\} \cup (\overline{x}^{(-)}, \underline{x}^{*}) \cup [\underline{x}^{*}, \overline{x}^{*}] \cup (\overline{x}^{*}, \underline{x}^{(+)}) \cup \{\underline{x}^{(+)}\} = [\overline{x}^{(-)}, \underline{x}^{(+)}], \qquad (6)$$

where $\overline{\overline{X}}^{**} = [\underline{x}^{**}, \overline{x}^{**}]$ is the outer reference interval for constructing the fuzzy estimate of the parameter X;

$\underline{x}^{**}$, $\overline{x}^{**}$, are respectively the lower and upper bound of the outer reference interval $\overline{\overline{X}}^{**}$, based on the ratio (6): $\underline{x}^{**} = \overline{x}^{(-)}$, $\overline{x}^{**} = \underline{x}^{(+)}$.

The outer reference interval assumes the interpretation as the outer approximation of the support for the sought-for fuzzy estimate. Thus,

$$\underline{x}^{**} \le \underline{x}^{0} < \overline{x}^{0} \le \overline{x}^{**}. \qquad (7)$$

On the basis of the obtained by the method described above inner and outer reference intervals, which are considered as an approximation of the core and support of the fuzzy number $\tilde{X}$, the representation of the latter is performed. The available standardized variants of the fuzzy numbers allow to effectively implement this step. Their use also implies the introduction of any additional hypotheses on the part of the expert regarding the properties of a financial and economic parameter under study, which is necessary to ensure a greater model certainty of its estimation.

Let us say, the expert can assume that the inner reference interval coincides with the core, and the outer reference interval – with the closure of the support of the sought-for fuzzy estimate. In this case, it can be modeled as a trapezoid number with the specified characteristics of the core and support. Similarly, the assumption about the unimodal character of a financial and economic parameter under consideration, as well as the smoothness of its membership function, allows to construct it using a membership function of Gaussian type with finite support, for which the mode equals the class mark of the inner reference interval, and the closure of the support coincides with the outer reference interval.

Based on the essence of the presented approach to finding fuzzy estimates of input financial and economic parameters of real investment, it is logical to call it the method of reference intervals. Let us consider the implementation of the proposed method using a conditional calculation example.

Assume that specialists of an enterprise analyze the economic attractiveness of an investment project for the production and sale of a new product. Due to the dynamic market conditions and the lack of relevant statistical data, most of the input financial and economic parameters of the project under study are estimated in the form of a fuzzy set (fuzzy-numbers). In this case the price for the product is forecasted based on the method of reference intervals. After performing the necessary analytical procedures, for the specified parameter the following estimates of the reference intervals were obtained. For the inner reference interval – $\overline{\overline{P}}^{*} = [\underline{p}^{*}, \overline{p}^{*}]$: $\underline{p}^{*} = 70$ dollars, $\overline{p}^{*} = 90$ dollars. For the outer reference interval – $\overline{\overline{P}}^{**} = [\underline{p}^{**}, \overline{p}^{**}]$: $\underline{p}^{**} = 40$ dollars, $\overline{p}^{**} = 100$ dollars.

Based on the available reference intervals, it is necessary to find a fuzzy estimate of the price for the product $(\tilde{P})$.

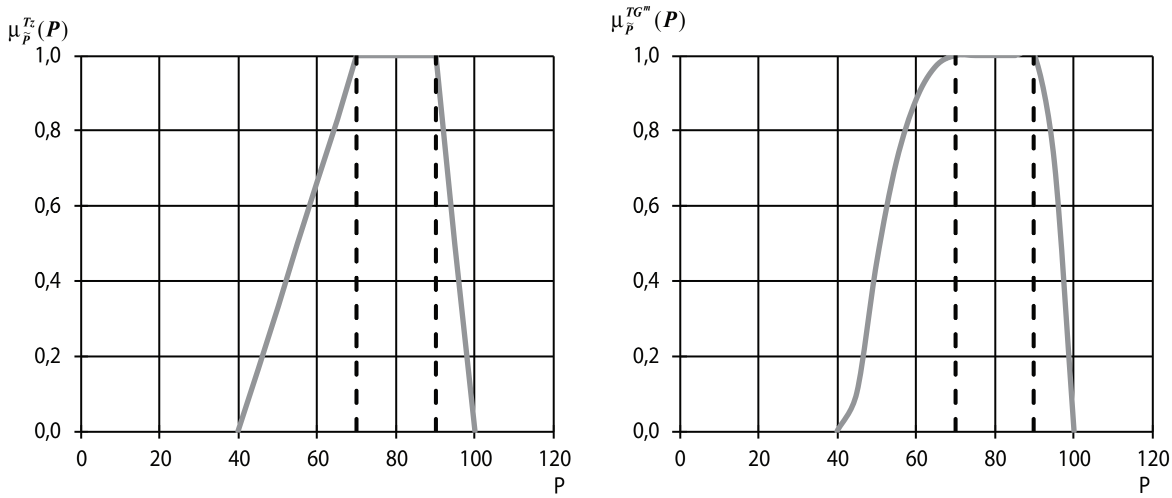
As noted above, modeling fuzzy estimates of a certain parameter by means of the reference interval method involves the use of standardized variants of fuzzy numbers. If within the considered conditional situation we refer to a trapezoid fuzzy number [8, p. 148–152], as well as a tolerant fuzzy number based on a membership function of Gaussian type with finite support [17, p. 42–43], then fuzzy estimates of the price for products can be obtained, the graphs of which are shown in Figure 1.

In addition to choosing a specific variant of a fuzzy number for the unambiguous representation of the sought-for fuzzy estimate, in each case the hypothesis was accepted that the inner reference interval coincides with its core, and the outer reference interval – with the closure of its support.

Conclusions. In general the results of the presented research give grounds to state that the modern fuzzy set methodology contains a rather developed arsenal of methods for constructing the membership functions of fuzzy sets, a certain part of which can be used for analyzing and evaluating economic efficiency of real investment. At the same time, the problem of estimating input financial and economic parameters of investment projects has its own peculiarities, thus when addressing it, the turning to general approaches should be complemented by elaborating and developing special methods. Such special methods, in particular, are the method based on quasi-statistics, as well as the method of reference points.

In the work, there proposed a method for finding fuzzy estimates of input financial and economic parameters of real investment, named according to its logic as the method of reference intervals. The constructive principle of this method is to represent a sought-for fuzzy estimate using the interval approximations of its core and support. The specified interval approximations, which are interpreted as reference intervals, are determined on the basis of the principles of the theory of rough sets.

It should also be noted that the current direction of further scientific research on the issues addressed in the publication is the development of a methodological apparatus to consider the combined (heterogeneous) uncertainty in the structure of input data when modeling economic efficiency of real investment.



1.1. Trapezoidal fuzzy estimate of the price for the product

1.2. Fuzzy estimate of the price for the product based on a membership function of Gaussian type with finite support

Fig. 1. Possible fuzzy estimates of the prices for products obtained by means of the reference interval method

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