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FUZZY MATHEMATICAL MODELLING IN ECONOMICS OF AN INNOVATIVE CHEMICAL PROJECT BY SIMPLEX OPTIMIZATION OF MIXTURES

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Abstract

The model of the best ratio of factors (criteria) where x1 is the product price, x2 is the discount rate "r", and x3 is the number of years of a project life "k" for the net present value(NPV) and the return on capital of the innovative chemical project. The presented model makes it possible to formulate a fuzzy set {A = the best value of NPV/ return on capital} if it is possible to influence the factors x1, x2 and x3, as well as any fuzzy sets {A = the best value of NPV/ return on capital} in a case if the product price change, the discount rate or the number of years of the innovative chemical project "Copolymer +" life did not dependent on activities of an innovation owner. Each cost was expressed as a triangular or trapezoidal fuzzy set instead of single-value initial data. The final result was also obtained in the form of a triangular or trapezoidal fuzzy set which gives a wide range of information about possible options. In order to optimize the search for the best set of factors for the innovative chemical project which make the best value of net present value and return on capital, a simplex-lattice design was used. Simplex optimization for three-component models with visualization of the results in the form of an isoline map, with support for designs of 2, 3, 3.5 and 4 orders was used.

Keywords: *mathematical modeling in economics, net present value, capital return, uncertainty, fuzzy sets, innovative chemical project, simplex optimization.*

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INTRODUCTION:

At present, the economy of the chemical industry has a number of specific features. First of all, this is due to the fact that a final product can be made from different raw materials and at the same time, a wide range of products can be obtained from a single raw material. In the chemical industry, which is characterized by rapidly developing science and a high degree of commercialization, one of the most effective approaches to mathematical modeling in economics is fuzzy logic. Nowadays, fuzzy-based modeling is one of the most modern and effective applied research and trends in management and decision-making.

Literature review

When solving the problem of inflexibility and incomplete use of unambiguous estimates of cost data, the concept of fuzzy sets theory can be used to eliminate uncertainty in the analysis of cash flows. In real life, decisions sometimes have to be made in the context of incomplete knowledge. It is very likely that decision makers evaluate based on their knowledge, experience and subjective judgment. If expenditure data are not fully known, linguistic terms such as "about 5 years", "approximately 25,000 to 50,000 dollars", "about 8%" are used for evaluation. Fuzzy logic can play a significant role in decision-making under uncertainty, because it is focused on the rationalization of uncertainty.

Approaches of the fuzzy sets theory have been known since the 1920s, but as an independent field of scientific knowledge it was formally formulated by the American Professor L. Zadeh in 1965 [1-2]. The fuzzy sets theory is primarily related to the quantitative assessment of uncertainty in human thoughts and perceptions. The theory allows us to formalize linguistic uncertainties, as well as apply mathematical operators such as addition, subtraction, multiplication and division in a fuzzy domain. Therefore, a fuzzy number can also be used in economic analysis to replace a single valuation of costs to their fuzzy values.

To characterize the fuzzy measures of linguistic uncertainties, many researchers focused on trapezoidal fuzzy numbers [3-5], instead of using a simple triangular number. The reason for using a trapezoidal fuzzy number is that it is more characteristic of linguistic estimates in economic analysis [6]. For example, an expert often indicates that the first investment is likely to be from 15 to 17 million rubles, but it can reach 12 or 19. In this situation, the investment can be designated as a fuzzy number (12, 15, 17, 19). In fact, a triangular fuzzy number is a particular case of a trapezoidal fuzzy number. When the two most probable values have the same value, the trapezoidal fuzzy number becomes a triangular fuzzy number as a special case [7]. Consequently, trapezoidal fuzzy numbers can be used in economic-mathematical calculations with a large number of situations.

In such studies, each value is usually indicated as a fuzzy set (a, b, c, d), where a is the smallest possible value, b and c determine the range of the most promising values, and d is the maximum possible cost value. In such a case, the results of the monetary costs analysis on the basis of discrete and continuous fuzzy numbers differ by their intervals of fuzziness.

In economic efficiency studies for innovative projects that do not have a large amount of data for the past years, as those are new projects by definition, the greatest difficulties are caused by uncertainties in future profits and costs. As a result, one should expect inaccurate calculation of many criteria for an innovative project, such as: net present value (NPV), profitability index (PI), internal rate of return (IRR), and modified internal rate of return (MIRR), payback period (PP) and discounted payback period (DPP).

In the situation of a single alternative, the solution can be adopted by comparing a finite fuzzy set with zero [8]. If a final fuzzy set is greater than zero, the project is desirable. Otherwise, it should be rejected. Sometimes it is unclear whether it can be determined whether the fuzzy set is greater than zero or not. There are two approaches to solve this problem. The first is that you can try different ranking methods, and then make a decision. The second way is to revise a fuzzy set as initial data for all types of costs.

If the range of the finite fuzzy set is sufficiently small, a preferred alternative can be chosen more clearly. On the other hand, if the final fuzzy set covers a wide range of values after analyzing the cash flow, then the final decision will be very difficult to achieve [9-11]. The purpose of the uncertainty analysis is to evaluate the effect of changes in cost data on the final fuzzy set.

The general method of reducing the range of a fuzzy set is called α-section, where α is the membership degree. The range of the fuzzy set can be reduced with correctly assigning the value of α. In this study, we will consider the possibility of using theα- section to reduce the range of fuzzy numbers.

An example of a portfolio of the innovative chemical project "Polycarbonate analogs" [12-14] will be used to illustrate the concept of choosing the best alternative by the simplex optimization of mixtures. It should be noted that uncertainty analysis is unique for every economic problem.

Study methods and phases

In order to optimize the search for the membership degrees of the factors of the innovative chemical project [15-16] which make up the best value of the net present value and the return on capital, a simplex lattice design was used. Simplex optimization for three-component models with visualization of results in the form of an isoline map, with support for designs of 2, 3, 3.5 and 4 orders was written in Delphi 5.0. The Sheffe formula was accepted as an approximating polynomial which has the following general form:

$$\tilde{y} = b_0 + \sum_{1 \le i \le q} b_i x_i + \sum_{1 \le i \le j \le k \le q} b_{ijk} x_i x_j x_k$$

Experiments were carried out for all lattice points 3:3, and after that responses are determined. Figure 1 shows their marks. The number of indices for responses and the degree of a polynomial must be equal. The membership degrees of innovative chemical projects in the best investment portfolio show the number of indices.

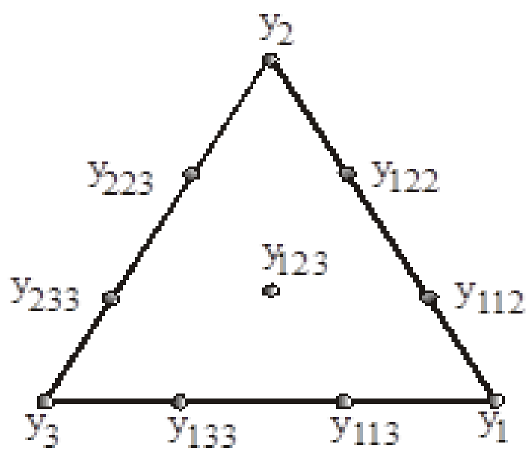

Fig. 1: Marking of responses at points of a simplex lattice

Table 1 presents the responses and the design based on the simplex 3:3.

Table 1: Responses and design based on the simplex 3:3.

№№	Latticenodes			Values	№№	Latticenodes			Values
	X 1	X 2	X 3			X 1	X 2	X 3	
1	1	0	0	y_1	6	0	1/3	2/3	y_1
2	0	1	0	y_2	7	2/3	1/3	0	y_2
3	0	0	1	y_3	8	2/3	0	1/3	y_3
4	1/3	2/3	0	y_{122}	9	0	2/3	1/3	y_{122}
5	1/3	0	2/3	y_{133}	10	1/3	1/3	1/3	y_{133}

Taking into account that the simplex lattices are filled, a substitution was used to determine the polynomial coefficients. This means that the coordinates of the points are alternately placed one after the other in the polynomial in order to derive formulas for calculation.

THE RESULTS OF THE STUDY AND THEIR PRACTICAL IMPORTANCE:

Let's make a model of the best ratio of factors (criteria) where x1 is a product price, x2 is a discount rate "*r* ", and x3 is the number of years of project life "k" for the net present value(NPV) and the return on capital of the innovative chemical project [17-18].

Net present value shows the amount of profit from the implementation of the innovative project, taking into account the return of investment to the investor and the discount rate. NPV of the innovative projects portfolio is the sum of NPVs of each project that make up this portfolio. Taking into account the weighting coefficients of each project in the portfolio, the total value is found by the additive convolution method. Such an opportunity makes net present value the main method of estimating the economic efficiency of the innovative project from such values as the profitability index (PI), the internal rate of return (IRR) and the modified internal rate of return (VIRR), the discounted payback period (DPP).

$$NPV = \sum_{k=1}^{n} \frac{P_k}{(1+r)^k} - \sum_{j=1}^{m} \frac{IC_j}{(1+i)^j}$$

With such an analysis in a fuzzy environment, it is necessary to take into account that an increase in the price of a product simultaneously leads to a decrease in the volume of sales; reduction of the discount rate "*r*" leads to a decrease in investment volumes, and, consequently, to a decrease in production volumes. The increase in the number of years of project life "*k*" leads to an increase in its risk level due to various factors (intra- and external economic and political, investment, innovation, business, commercial, raw materials, industry, etc.). As a result, the fuzzy value of NPV and the return on equity will shift to the left. We cannot exert any influence on the predicted level of inflation "*i*".

So, we build a model of the correspondence between the membership degrees of these three factors in the maximum NPV values (Figure 2) and the return on capital (Fig.3).

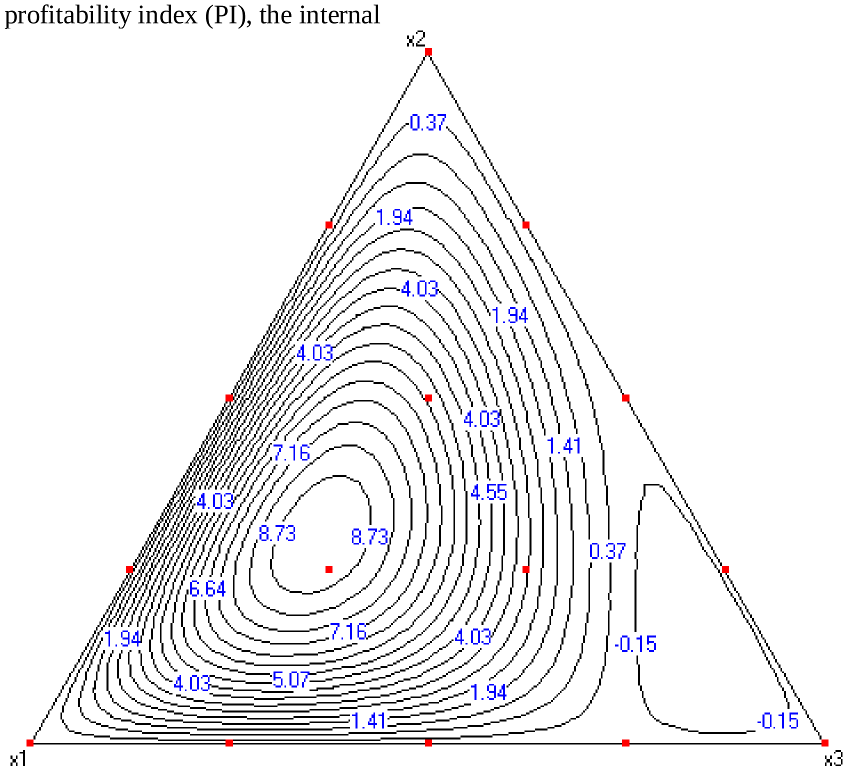

Fig. 2: Simplex optimization of the best NPV value of the innovative chemical project "Copolymer +" in conditions of uncertainty of the product price x1, discount rate x2, and the number of years x3.

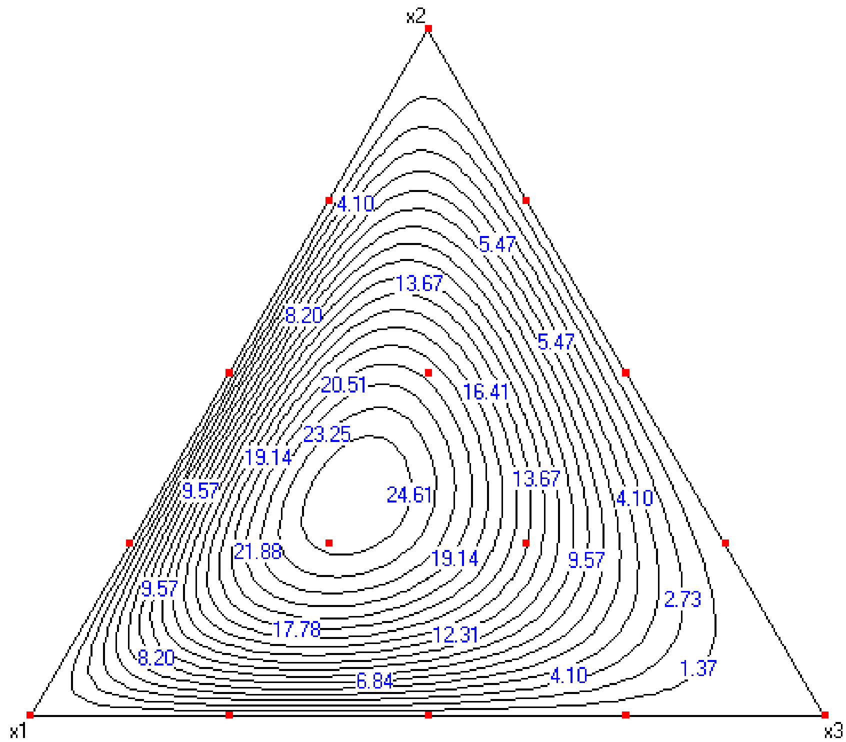

Fig. 3: Simplex optimization of the best value of the return on capital for the innovative chemical project "Copolymer +" in the context of the uncertainty of the product price x1, the discount rate x2, and the number of years x3.

CONCLUSIONS:

The presented model allows us to formulate a fuzzy set {A = the best value of NPV / Return on Capital} in case of possible influence on the factors x1, x2 and x3: $A \approx \left\{ \frac{0,5}{x1}, \frac{0.25}{x2}, \frac{0.25}{x3} \right\}$, as well as any fuzzy sets {A = the best value of NPV / Return on Capital} in the event of a product price change, a discount rate or the number of years of life of the innovative chemical project "Polycarbonate Analogs"do not depend of the innovative entrepreneur actions.

SUMMARY:

Analysis of cash flows is necessary to make informed decisions in economic and mathematical research. If there are sufficient data on costs, then successful decisions can be made on the basis of traditional approaches. Unfortunately, decision-makers rarely have enough information to conduct economic analysis. Moreover, since unambiguous estimates are used in traditional economic analysis, a small change in the cost data can cause a completely wrong decision. However, a good alternative can be ignored because of a minor error in estimating the cost data.

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