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Larisa Ostankova*
Natalya Shevchenko**

ACCOUNT-TAKING OF EFFECT OF MICRO- AND MACROENVIRONMENT ON INVESTMENT DECISION TAKING UNDER THE CONDITIONS OF INDEFINITENESS

Abstract: *The mechanism of an estimation of efficiency of investment projects taking into account risk and vagueness is offered. At a choice of the optimum investment project industrial risks and risks of macroeconomic character are considered. Methods integral calculations, Hurst's method, neural network's modeling, imitating modeling, elements of the theory of fuzzy sets are used. The considered algorithm allows to raise quality of accepted administrative decisions at ranging and a choice of variants of real investment.*

Key words: *real investments, the investment project, risk, vagueness, neural network, imitating model, fuzzy set, linguistic variable, the analysis by criteria.*

RAZMATRANJE DEJSTVA MIKRO I MAKRO OKRUŽENJA NA DONOŠENJE ODLUKE O ULAGANJU U USLOVIMA NEODREĐENOSTI

Sažetak: *Rad predstavlja mehanizam procene efikasnosti investicionih projekata koji uzima u obzir rizik i neodređenost. Prilikom izbora optimalnog investicionog projekta u obzir se uzimaju industrijski rizik i rizik makro ekonomskog karaktera. Koriste se metode integralnih proračuna, Hurst metod, model neuronske mreže, oponašajući model, elementi teorije o fazi skupovima. Razmotreni algoritam omogućava da se podigne kvalitet donošenja upravnih odluka i izbor varijanti realnih investicija.*

Ključne reči: *realna ulaganja, investicioni projekat, rizik, neodređenost, neuronske mreže, oponašajući model, fazi skup, jezičke promenljive, analiza pomoću kriterijuma.*

The modern economic system in Ukraine was taking its shape preferably by the exogenous model, while the overriding development of the export-centered enterprises of the fuel-and-power and metallurgical complexes determined the essence and shape of this model.

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* Larisa Ostankova, the candidate of economic sciences, Kramatorsk Institute of Economics and Humanities (KEGI), Ukraine, Kramatorsk

** Natalya Shevchenko, the candidate of economic sciences, The Donbass State Machine-building academy, Ukraine, Kramatorsk

Unfortunately, the export expansion of these industries did not go in line with a technological breakthrough, whereas the production process based on exploiting cheap fuels and low-productive workforce incurred heavy expenditures. On the whole, the situation was typical to that of the former administrative system. What largely aggravated this situation was the economic crisis and a steep downfall in the market demand for raw materials.

Therefore the development strategy for enterprises in these industries needs to be urgently corrected to stabilize and increase the economic competitiveness of this country in the world market, particularly by way of effective use of the systems of strategic and internal company planning, their development and improvement. Incidentally, it is the investment strategy of development that requires to be improved, and this priority is determined by a considerable material and power consumption involved in industrial products of the key economic branches, with a high depreciation rate of the basic production assets into the bargain.

Research in the sphere of shaping the strategy of investment development was advanced by I. Blank, A. Peresada, I. Buz'ko, O. Vartanova, V. Borisov , G. Kasarov, O. Lyashenko, S.Spivack and others. Such scholars as A.Altunin P. Verchenko, V. Vitilinsky, O. Gneny , I. and others made an appreciable contribution into the tasks of solving the problems of investment activity modeling, strategy of investment development of economic systems and the risks involved.

For all appreciable scientific results in the sphere of strategic planning, investment activity and development modeling as well as risk taking decisions, quite important remains the task of elaborating the formalized mechanism of taking managerial decisions concerning investment development of an industrial enterprise under the conditions of unstable economic environment, aimed at gaining additional profit and material saving.

Taking into account the fact of the investment activity being aggravated by internal and external risks, it is expedient to have their qualitative assessment for taking a well-grounded managerial decision in the process of forming a planned strategy of an industrial enterprise investment development. An effectiveness index of an investment variant on the basis of which a choice is made must take into account the information concerning the conditions of the project implementation and thus the probability of risk situations and their consequences.

The aim of the given research is a choice of an optimum variant of investments based on accounting for the risks involved with the help of the methods of economic-mathematical modeling under the conditions of indefiniteness.

An important index for evaluating economic effectiveness of investment projects is a net present value (NPV – net present value):

$$NPV = \sum_{t=0}^{n} \frac{NCV_t}{(1+R)^t}, \quad (1)$$

where NCV_t – net flow of cash during t-interval of the planned period; R – a discount rate that account for a risk; t – an ordinal number of an interval of planning provided the beginning of the project implementation is taken to be a zero.

In the given case, the risk, which is estimated by a particular figure of the net present value, depends on the discount rate. That is why, for the purpose of complex accounting of the investment project risks, index R of the discount rate is modified, discount rate being a component of the net present value as the main indicator of evaluation of investment projects economic effectiveness. The discount rate is shown as an integral index, or indicator, whose components are a risk of the machinery breakdown and a risk of "economic catastrophe". [1]

The task is formulated as follows. The process of product manufacture is accompanied by profit gaining with intensity $x(t)$ analogous to the principles of the system of mass service. The profit for a short interval of time will amount to $x(t)dt$ [1]. Let's assume that the relationship between profit and depreciation of basic equipments has an exponential character:

$$x(t) = a \cdot X \cdot e^{-b \cdot t}, \tag{2}$$

where a – a constant, the value of which can be calculated by means of regression analysis; b – expenditures on capital repair of basic production assets; X – profit before implementing a managerial decision; T – service life of basic means of production.

A condition for cessation of an investment project realization, taking into account that real investment is taking place, is represented by a marginal level of profit. This level is determined by a person who takes a corresponding decision, that is $x(T) = g$, where T – the term of the project realization.

The profit obtained from realization of the project is to be calculated by the formula of the profit which is integrated in the $0 \div T$ interval with the discounting coefficient $e^{-R \cdot t}$, where R – discounting rate:

$$V = \int_0^T x(t) \cdot e^{-R \cdot t} dt = \frac{a \cdot X}{R+b} - \frac{a \cdot X \cdot e^{-(R+b) \cdot T}}{R+b}. \tag{3}$$

Taking into account the probability of each of the risk situations considered in the $[0; dt]$ interval, we introduce a number of denotations : pdt – probability of the equipments breakdown, Q – average number of malfunctioning per hour $[0; \tau]$, τ – time for equipments repair, v – cost of repair, λ – intensity of malfunctioning while accounting for the fact that the time required to eliminate shutdowns is liable to the exponential law of distribution. Then the mathematical probability of the discounting coefficient has the following kind:

$$q = M[\tau] = \frac{1}{Q}\int_0^\infty e^{-R_1\cdot\tau}\cdot e^{-\frac{\tau}{Q}}d\tau. \tag{4}$$

Hence

$$q = \frac{1}{Q}\int_0^\infty e^{\frac{-R_1\cdot\tau\cdot Q-\tau}{Q}}d\tau = \frac{1}{Q}\int_0^\infty e^{\frac{-\tau\cdot(R_1\cdot Q+1)}{Q}}d\tau = \frac{1\cdot Q}{Q\cdot(R_1\cdot Q+1)}\int_0^\infty \frac{(R_1\cdot Q+1)}{Q}\cdot e^{-\tau\cdot\frac{(R_1\cdot Q+1)}{Q}}d\tau. \tag{5}$$

Thus $q = \dfrac{1}{1+R_1\cdot Q} = \dfrac{\lambda}{\lambda+R_1}$.

The mathematical probability of the discounted expenditures related to a unit of malfunctioning, taking into account that z – expenditures for repair per unit of time, is described by the formula:

$$C = M_\tau[v] = \int_0^\infty M_\tau[z]\cdot e^{-\tau\cdot\lambda}d\lambda\tau, \tag{6}$$

where

$$M_\tau[z] = \int_0^\tau z\cdot e^{-R_1\cdot t}dt = z\cdot\int_0^\tau e^{-R_1\cdot t}dt = z\cdot\left.\frac{e^{-R_1\cdot t}}{-R_1}\right|_0^\tau = \frac{-z}{R_1}\cdot(e^{-R_1\cdot\tau}-1), \tag{7}$$

that is why

$$C = \int_0^\infty \frac{-z}{R_1}\cdot(e^{-R_1\cdot\tau}-1)\cdot e^{-\tau\cdot\lambda}d\lambda\tau = \frac{-z\cdot\lambda}{R_1}\cdot\left[\int_0^\infty e^{-R_1\cdot\tau}\cdot e^{-\tau\cdot\lambda}d\tau - \int_0^\infty e^{-\tau\cdot\lambda}d\tau\right] =$$

$$= \frac{-z\cdot\lambda}{R_1}\cdot\left[\frac{1}{R_1+\lambda}\cdot\int_0^\infty (R_1+\lambda)\cdot e^{-(R_1+\lambda)\cdot\tau}d\tau - \frac{1}{\lambda}\cdot\int_0^\infty \lambda\cdot e^{-\tau\cdot\lambda}d\tau\right] = \frac{z\cdot q}{\lambda}. \tag{8}$$

During the interval $[0; dt]$ with probability kdt an economic catastrophe will occur which will result in the production shutdown – the integral discounted profit from the subsequent functioning of the profit will gain a zero value. That is why in the $[0; dt]$ interval with the $[1-(p+k)]dt$ probability the realization of the investment project (industrial process) will be taking place in keeping with plan: over the time dt the profit will amount to $x(t)dt = X\cdot a\cdot e^{-b\cdot t}$, its value will get changed in line with ageing of the basic equipments, with an account of bdt. During the shutdown of the equipments no catastrophes are considered to be possible.

Then the integral discounted profit with an account of probabilities of risk situations has three component parts:

1) functioning by the plan: $[1-(p+k)]dt\cdot x(t)dt\cdot e^{-R_1\cdot t}$;

2) functioning with an account of the production equipment shutdown: $pdt \cdot [q \cdot x(t)dt - C]$;

3) shutdown of the production process because of economic catastrophe: $kdt \cdot 0$.

As a whole the value of the integral discounted profit from realization of the project has the following appearance:

$$Vruzuk = \int_0^T X \cdot a \cdot e^{-b \cdot t} \cdot e^{-R_1 \cdot t} \cdot (1 - p - k)dt + \int_0^T \left(q \cdot X \cdot a \cdot e^{-b \cdot t} - C\right) \cdot pdt + \int_0^T 0 \cdot kdt =$$
$$= \left[\frac{X \cdot a}{b + R_1} - \frac{X \cdot a \cdot e^{-T \cdot (b + R_1)}}{b + R_1}\right] \cdot (1 - p - k) - C \cdot p \cdot T - \frac{1}{b} \cdot q \cdot p \cdot X \cdot a \cdot e^{-b \cdot T} + \frac{1}{b} \cdot q \cdot p \cdot X \cdot a. \quad (9)$$

Accounting for (8), aggregation of the guaranteed discount rate and probabilities of risk situations into one index is done by way of comparing two functions of profit: before accounting the factors of risks and with accounting the probabilities of risk situations and their consequences. The values of the coefficient of discounting are calculated from this equation by the numerical method of solving non-linear equations – by the method of iteration.

To determine the probability of malfunctions in operation of the equipment, we will make the following assumptions:

- as a unit of equipment from the overall park of equipment is offered for replacement, then as malfunctions will be considered shutdowns for capital repair of any piece of equipment, which entails the shutdown of production process;
- for realization of the proposed model, the most important thing is to define a probability of the two states of the production system: absence or presence of the equipment shutdown.

Let us examine system S – a shop production equipment which stops its operation due to a flow of faults and failures with intensity λ. By the data of the statistical analysis of violations in the process of work of the shop equipment, the following has been obtained over the previous periods: once any breakdown is detected restorative work immediately begins; analysis of time intervals between capital repairs has shown: the average value of interval m of years, the average quadrant deviation of the interval – σ років. Meanwhile it is noted down that there are only two real states of the system: S_1 – equipment operates; S_2 – equipment went out of order. [2] However transfer from state 2 into system state 1 occurs under the influence pf the Erlang flow, that is why the system processes do not belong to Markov decision processes. It is necessary to render this process to a kind of Markov decision processes, for which we introduce three subsidiary states : S_2^1 – repair begins; S_2^2 – repair continues; S_2^3 – repair finishes. In this way we break the repair three phases, the time of each phase being subdivided by the exponential law.

Further it is necessary to define the characteristics of the Erlang flow. The use of this variety of the Palm flow is conditioned by the fact that with the help Erlang flows it is possible to reduce non-Markov processes to Markov type. In our case, the process of the equipment getting out of good repair cannot be treated as Markov type because the quality of the equipment operation depends on the time of its work, that is it has the effect of afteraction.

As a flow order, we select the nearest whole figure $k = 3$. Thus we have gained the Erlang flow of the 3d order with density of the kind:

$$F(t) = \frac{(kf)^k}{(k-1)!} t^{k-1} e^{-kft} = \frac{(3 \cdot 0{,}51)^3}{2!} t^{21} e^{-3 \cdot 0{,}51 \cdot t}.$$

We have thus obtained that a random duration of repair time is subdivided by Erlang law of the 3d order and it represents the sum total of three random values t_1, t_2, t_3, which are subdivided by the exponential law with the parameter $\mu = f \cdot k$: $F_1(t) = \mu e^{-\mu t}$, $(t > 0)$. In the result of changing the system initial states by diagram 2 we have got a Markov process for which marginal probabilities can be found out. Let's denote marginal probabilities of the subsidiary states of the system with p_2^1, p_2^2, p_2^3, then $p_2^1 + p_2^2 + p_2^3 = p_2$. We denote $\overline{t_1} = \frac{1}{\lambda}$, $\overline{t_2} = \frac{1}{\mu}$.

Marginal probabilities of the system states will look as follows:

$$\left.\begin{aligned}
p_1 &= \frac{\overline{t_1}}{\overline{t_1} + 3\overline{t_2}}; \\
p_2^1 = p_2^2 = p_2^3 &= \frac{\overline{t_2}}{\overline{t_1} + 3\overline{t_2}}; \\
p_2 = p_2^1 + p_2^2 + p_2^3 &= \frac{3\overline{t_2}}{\overline{t_1} + 3\overline{t_2}}.
\end{aligned}\right\}$$

Meanwhile, the value $3\overline{t_2}$ is the sum of the average time during which the system is found in each subsidiary phase. Bearing in mind that $\overline{t_1} = \frac{1}{\lambda}$ та $\overline{t_2} = \frac{1}{\mu}$, we obtain:

$$p_1 = \frac{\mu}{\mu + 3\lambda}, \quad p_2 = \frac{3\lambda}{\mu + 3\lambda}.$$

We have thus got the probability of the equipment malfunction as $p_1 = 0{,}144$.

An index of the gross domestic product serves as a parameter for evaluation of stability of the political and economic system. This summarizing index is used as an external factor of the risk.

To define the economic stability it is expedient to make use of the principles of the "chaos theory". Related to this, a hypothesis is put forward about the fractal properties of the country's economy and, as a consequence, about the symmetry and durable memory.

We shall formulate the following prerequisites for analysis:

- gross domestic product is considered to be a basic economic index of a national state;
- increase of the gross domestic product testifies to the growing tendencies of the whole economic system;
- amount of the gross domestic product depends on many risk factors (political stability, international relations, development of people's economy), which conditions the probability character of this index.

Thus we put forward the hypothesis about the fractal character of subdividing the values of the gross domestic product.

To investigate the fractal time series of the gross domestic product (GDP) we shall make use of the R/S method [3–4], which is based on the analysis of the amplitude of the value parameters. This methods contains a minimal assumption in respect of the object being analyzed, it can classify the time line, and it differentiates a random line from a non-random one even if the line is not normally subdivided.

To classify the time series Hurst introduced dimensionless relationship by way of dividing the amplitude by the standard deviation of observations. In keeping with [3–4] the majority of the phenomena correspond to „casual wandering with a certain shift" – a trend with noise. The trend strength and the noise level are estimated by the value of the normalized amplitude during the time.

According to the statistical mechanics, the Hurst index must be 0.5, f the series is made up of random wanderings (the amplitude of accumulated deviations must increase in proportion to the square root from the time n).

The chaos theory witnesses that any non-linear system has a point in its motion where the memory about the initial conditions is lost. This point corresponds to rounding off, or completing, of the system period. Proceeding from this: the processes with long-term memory are not endless, they have a limit. The length of the memory depends on the system structure which generates the fractal time series. That is why a regression must be built by the end of a corresponding period, and a conclusion about the process with a long-term memory must be made on the basis of the mark H.

Further to define the Hurst index it is necessary in the dual logarithmic coordinates to find an angle R/S as function from n.

A direct line in the Figure corresponds to $H = 0.657$. The process with a long-term memory is observed approximately over 12 months which corresponds to the cycle size of the given system. After this point random wanderings can be seen, as well as how the diagram sharply deviates from the initial trajectory. On the basis of the regression data within the cycle of eleven months the Hurst index amounts to $H = 0.657 \pm 0.0695$ – this is an average value as the system is non-periodic and fractal.

In the result the Hurts index differs significantly from the value of 0.5. This means that the observations are not independent, each observation bears the memory about the previous data – a long-term memory. In the long-term scale the economic system which gives the Hurst characteristics is a result of a long flow of the related events. The present state of the system is determined by the past and it depends on time. The time is an iterative process where the influence of the past on the future is defined by the correlation relationship (Batten, 2001: 27): $C = 2^{2H-1} - 1 = 0.32$.

As $0.5 < H = 0.657 < 1.0$, we have маємо a persistent (trens-stable) series. Trend stability increases when the Hurst index approaches to 1, while correlation is an additional value.

The fractal dimensionality of the GDP values makes $D = 2 - H = 2 - 0.7 = 1.3$ (the fractal dimensionality 1.5 corresponds to random wanderings), which testifies to the presence of the persistent time series, which yields a flatter curvature and characterizes the system which undergoes fewer changes.

To confirm evaluation of the Hurst index we shall employ the method which is based on defining a standard deviation for different stages of averaging (Chasser,1974: 28–38). In this case the Hurst index is defined by the bend angle of the diagram of the logarithmic standard deviations *SD* of the aggregate series. The Hurst index amounts to $H = 1 - \beta / 2$ (β – angle coefficient), $H = 0.7 \pm 0.029$, which coincides with the earlier obtained value of this index for the monthly values of the GDP.

Thus a very high estimation of the Hurst index, which is obtained by two methods, confirms the hypothesis of the fractal character of the GDP system of the Ukrainian economy. The country's economy is liable to random wanderings with a certain shift with anomalous value of $H = 0.7$.

To sum it up, it was defined with the help of the Hurst index that the economic system has a cycle of eleven months, which confirms importance of the presence of the system cycles, but not the quantity of separate observations which is typical for a usual statistical analysis. The necessity of employing fractals is determined by dependence of the system on the time, and it is possible to predict the character of the trend on the future periods in keeping with the duration of the memory of the given process. Thus the series analyzed, the fractality indice received and the Hurst value testify to the growing tendencies of the index of the gross domestic product within the Ukrainian economy.

So, under all other equal conditions, at $R_1 = 20\%$, $p = 0.144$, $k = 0.07$ the modified index of the discounting will amount to $R = 0.275$ or 27,5% (Fig. 1), which meets the condition $V \approx Vruzuk$.

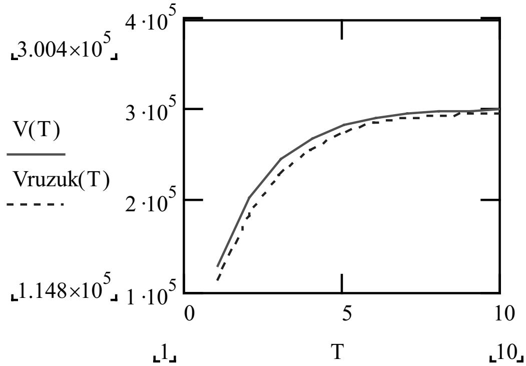

Fig. 1. Functions of the discounted profit during T years of realization of the investment project

As it has been already noted, the net present value turns out to be the most widespread method of evaluation of attractiveness and riskiness of the investment project. However the routine of calculation, specified in the economic analysis, accounts only for the discount rate to estimate the riskiness of the project as a weighted average or average expectable value. Incidentally, the investor never has at his disposal the earlier known data about the initial conditions of the project, variants of environmental behaviour and their quantitative expression. This situation entails a high level of indefiniteness.

Based on the statement that „defining random variables and imparting them a corresponding distribution of probability is an obligatory condition of running the risk analysis" [1], we employ the method of imitation modeling of the conditions of the investment project realization for the purpose of predicting the estimate of their effectiveness.

To determine an optimum variant of investing the funds it is necessary by means of the Monte-Carlo method to carry out generating of the basic components of effectiveness criterion of the investment project (net present value – NPV).

Defining the law of distribution of input parameters is a major problem of imitation modeling. If this problem can be solved by way of matching existing distribution laws to the real law of subdividing a random value by means of forwarding and proving a corresponding hypothesis, the investor is however facing an unsolved question of defining the characteristics of this distribution with taking into account the changes of the input parameters caused by particular conditions of realization of a concrete investment project: a normal law of distributing a random value is used.

To this end, two strategies of the real investment are proposed for analysis: the purchase of a new heating furnace with rolled-out bottom at 10 000 thousand hryvnia. (fuel saving up to 40 %, electrical energy saving up to 15 %) – the first alternative (Project A) and renewal of the functioning heat treatment furnace by means of modernization at 2800 thousand hryvnia. (fuel saving 15 %) – the second alternative (Project B).

Graphically the results of imitation with the help of the modified index of discounting rate $R = 0{,}275$, are represented by dependencies between the changes of the input and resulting indice of the imitation model (Fig. 2–3).

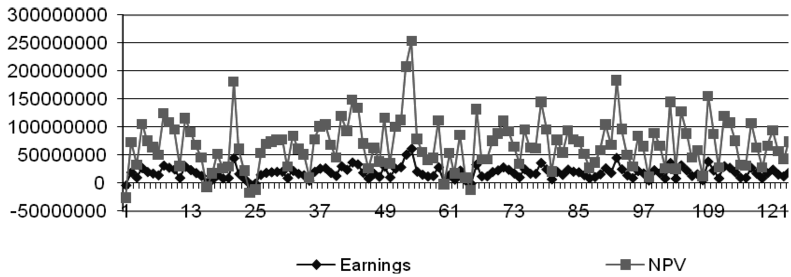

Fig. 2. Dependence between the amount of earnings and net present value, hrn. (alternative 1)

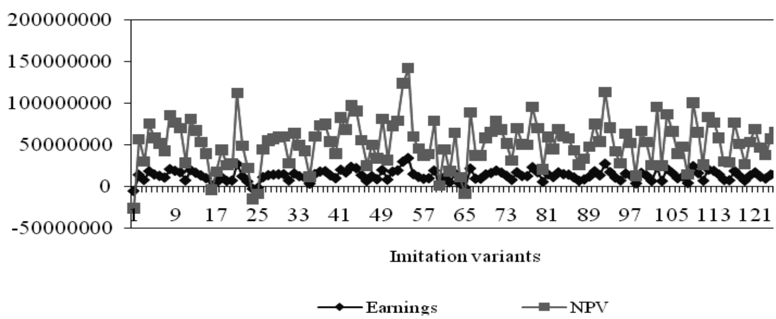

Fig. 3. Dependence between the amount of earnings and net present value, hrn. (alternative 2)

In the result of the imitation experiment, we have obtained the following expectable figures of the net present values for the first variant: $M(E) = 50{,}7$ million hrn. at $\sigma(NPV_1) = 32{,}5$ million hrn., $CV(NPV_1) = 0{,}64 < 1$, that is the risk of the given investment project does not exceed the risk level of the investment portfolio of the enterprise. The results of the probabilistic analysis show the losses risk at $P(E \leq 0) = 6\,\%$. With this, the probability of exceeding the average value $P(M(E) + \sigma(NPV_1) \leq E \leq Max(NPV_1)) = 16\%$, the probability of obtaining the amount of earnings within the interval $[\,M(NPV) - \sigma; M(NPV)]$ equals 34%.

For the second variant, $M(E) = NPV_2 = 39{,}4$ million hrn., and $CV(NPV_2) = 0{,}51 < 1$, that is the risk of the given investment project does not exceed the risk of the enterprise's investment portfolio and it is lower that the first alternative's risk. The probability of the losses incurred $P(E \leq 0) = 3\,\%$. The likelihood of obtaining the amount of earnings within the interval $[\,M(NPV) - \sigma; M(NPV)]$ also equals 34 %, analogous to the first project (Table 1).

The analysis of attractiveness of investment projects, under the conditions of taking a general managerial decision concerning the replacement of equipments in the process of implementing energy-saving technologies, requires accounting for the indice of net present value (K_1), the term of recoupment of capital investments (K_3) and profitability of investments (K_4). Besides, it is also worthwhile during this analysis to take into account, when estimating the effectiveness of investment projects, the amount of variable expenses (K_6), normative expenses on equipment depreciation per unit of gas consumption (K_5), normative expenses for equipment repair per unit of production (K_7), percentage of lowering of the product cost (K_8), overall average increase of the potential profit (K_9) and percentage of saving energy consumption (K_{10}). To get an integral picture of the analysis it is also proposed to enlarge the list of the coefficients with an index $V\ \&\ M$ – the index of riskiness of the investment project, which is calculated by the Voronov&Maximov formula (Nedosekin, 1999) on the basis of the fuzzy logic apparatus (K_2).

Table 1. Imitation results

Indice	**Results of imitation of a random value (E)**			
	Earnings, hrn		Net present value, hrn	
	Project A	Project B	Project A	Project B
Average value (M(E))	18456428	12822970	50677948	39357210
Satandart deviation (SIGMA)	9882036,5	6161982,6	32488502	20258333
Variation coefficient	0,54	0,48	0,64	0,51
Minimum (MIN)	-3814929,6	-5505507,9	-22542086	-20900086
Maximum(MAX)	61341966	33809354	191669828	108352723
Number of occurrences of losses	–	–	18	14
Probabilities				
P (E ≤ 0)	0,03	0,02	0,06	0,03
P (E ≤ MIN(E))	0,01	0,00	0,01	0,00
P (M(E) + SIGMA ≤ E ≤ MAX)	0,16	0,16	0,16	0,16
P (M(E) - SIGMA ≤ E ≤ M(E))	0,34	0,34	0,34	0,34

However in practice a conclusion on the choice of a more effective project out of the number of alternatives on the basis of quantitative estimates $K_1 - K_{10}$ is not simple. The reason for this is in the comparative estimation of the given indice of effectiveness when the quantitative analysis results don't eliminate an indefiniteness factor, that is they don't give a single answer.

It is proposed to use a fuzzy set approach as a method of removing indefiniteness during the quantitative and qualitative estimation of investment projects. The theoretical foundations and practical particularities of this approach are treated in the research works of this country's and foreign workers. Thus R. Belman and L. Zade, S. Blyumin and I. Shuikova examine main theoretical principles of the fuzzy logic; approaches to estimation of alternative variants of financial or expert models on the basis of the formalisms of fuzzy logic are treated in the works of L. Zade, S. Shtovba and A. Rotshtein, A. Nedosekin and O. Maximov; S. Orlovsky's research is devoted to the problem of decision-taking under the conditions of the vague output information.

Employing the above-mentioned scientific-and-practical achievements it is proposed to formulate an estimation scale of investment projects with taking into account weighting coefficients of effectiveness indice to take a correct managerial decision, while bearing in mind that the final investment decision is taken after all by the enterprise specialists on the basis of obtained quantitative calculations ($K_1 - K_{10}$), which might have a contradictory character.

The aim of our research is an elaboration of the mathematical model which will allow to take an optimum investment decision under the conditions of indefiniteness.

The task setting (Rotshtejn, Shtovba, 150–154). $P = \{p_1, p_2, ..., p_h\}$ – a set of investment projects which are liable to analysis by many criteria; $K = \{K_1, K_2, ..., K_m\}$ – a set of quantitative criteria for estimation of investment projects. The task of multiple-criteria analysis consists in ordering the set P elements by the criteria from the set K.

Assume that $\mu_{K_j}(p_h)$ is a number in the range [0,1], which characterizes the estimation level of the variant $p_h \in P$ by the criterion $K_j \in K$: the larger is the number $\mu_{K_j}(p_h)$, the higher is the estimate of variant p_h by criterion $K_j, j = \overline{1,m}, h = \overline{1,r}$. Then criterion K_j can be represented as the fuzzy set $\overline{K_j}$ on the universal set P:

$$\overline{K_j} = \left(\frac{\mu_j(p_1)}{p_1}, \frac{\mu_j(p_2)}{p_2}, ..., \frac{\mu_j(p_n)}{p_n} \right), \tag{10}$$

where $\mu_j(p_i)$ – a degree of membership of the element p_j to the vague set $\overline{K_j}$.

We resolve the membership function of the fuzzy set $\overline{K_j}$ by the method of building the matrix of paired comparisons. For employing .this method it is necessary to formulate the matrices of paired comparisons of the alternative investment variants by each estimation criterion. The total number of matrices corresponds to the number of criteria and it equals to m.

The best variant of investing is believed to be the one which happens to be the best by all criteria. The fuzzy solution R is found by crossing of the private criteria:

$$\overline{R} = \overline{K}_1 \cap \overline{K_2} \cap \ldots \cap \overline{K_j} = \left\{ \frac{\min\limits_{j=1,m} \mu_{\overline{K_j}}(p_1)}{p_1}, \frac{\min\limits_{j=1,m} \mu_{\overline{K_j}}(p_2)}{p_2}, \ldots, \frac{\min\limits_{j=1,m} \mu_{\overline{K_j}}(p_h)}{p_h} \right\}. \quad (11)$$

According to the fuzzy set $\overline{R}$ obtained, the best variant should be considered the one for which the membership degree is the largest.

To heighten the quality of the obtained decisions the disproportion of criteria is to be introduced:

$$\overline{R} = \overline{K}_1 \cap \overline{K_2} \cap \ldots \cap \overline{K_j} = \left\{ \frac{\min\limits_{j=1,m} \mu_{\overline{K_j}}(p_1)^{\alpha_j}}{p_1}, \frac{\min\limits_{j=1,m} \mu_{\overline{K_j}}(p_2)^{\alpha_j}}{p_2}, \ldots, \frac{\min\limits_{j=1,m} \mu_{\overline{K_j}}(p_h)^{\alpha_j}}{p_h} \right\}, \quad (12)$$

where α_j – coefficient of the relative importance of criterion K_j, $\alpha_1 + \alpha_2 + \ldots + \alpha_m = 1$.

The end result is defined by crossing the previous results by each expert: $\overline{P}_{opt} = \overline{R}_1 \cap \overline{R_2} \cap \ldots \cap \overline{R_l}$.

The index of degree α_j testifies to the concentration of the fuzzy set $\overline{K_j}$ in correlation to the extent of importance of the criterion K_j. The coefficients of the criteria relative importance are also defined on the basis of paired comparison matrices by the Saati scale separately for each expert. The importance level of each criterion is found out by crossing the fuzzy decisions obtained by each separate expert.

In the proposed model, an effective investment decision is described by a range of qualitative factors for estimation of an investment alternative (the number of factors $m = 10$). With this, all factors have a qualitative definition. To reduce the subjectivity level of the expert estimates, each index of the investment project is ranked for the purpose of imparting them weighting coefficients. This is done by means of introducing an additional fuzzy set „the most prioritized index of the investment project estimation" provided there is a certain set of experts $S = \{S_1, \ldots, S_z\}$, де $l = \overline{1.z}$, z – a number of experts:

$$\overline{S_l} = \left(\frac{\mu_j(k_1)}{k_1}, \frac{\mu_j(k_2)}{k_2}, \ldots, \frac{\mu_j(k_m)}{k_m} \right), \quad (13)$$

$\mu_l(k_j)$ – membership degree of element k_j to fuzzy set $\overline{S_l}$.

The fuzzy solution $\overline{U}$ is crossing the elements by each expert:

$$\overline{U} = \overline{S}_1 \cap \overline{S_2} \cap \ldots \cap \overline{S_z} = \left\{ \frac{\min\limits_{l=\overline{1,z}} \mu_{S_l}(k_1)}{k_1}, \frac{\min\limits_{l=\overline{1,z}} \mu_{S_l}(k_2)}{k_2}, \ldots, \frac{\min\limits_{l=\overline{1,z}} \mu_{S_l}(k_m)}{k_m} \right\}. \tag{14}$$

With this, the coefficient ranks have to be generalized at this particular stage to avoid accumulating the subjectivity of the expert estimates further:

$$\alpha_j = \frac{\min\limits_{l=\overline{1,z}} \mu_{S_{ll}}(k_j)}{\sum\limits_{j=1}^{m} \min\limits_{l=\overline{1,z}} \mu_{S_l}(k_{j1})}, \tag{6}$$

where $\sum\limits_{j=1}^{m} \alpha_j = 1$.

In the given paper, the degree of membership $\mu_A(x)$ of element x to the fuzzy set $\tilde{A}$ is interpreted as a subjective measure of the following: to what extent the element $x \in X$ corresponds to the notion which content/subject is formalized by the fuzzy set $\tilde{A}$. By the subjective measure we shall understand the degree defined by questioning the experts, namely the degree of correspondence of element x to the notion which is formalized by the fuzzy set $\tilde{A}$. The expert paired comparisons serve as output information to build the functions of membership. For each pair of the elements of the universal set the expert estimates an advantage of one element over the others in relation to the properties of the fuzzy set.

The linguistic variable will have an appearance to formalize the set „optimum project". At formalizing the set „the most prioritized index of estimation of the investment project". With this, each term is correlated with a fuzzy variable by Saati scale.

To define the membership functions a dual method is proposed which combines the method of statistical processing of the expert information and the paired comparison method for one expert. The dual method is used to evaluate the importance level of each criterion in estimation of the investment project separately for each expert; further the function of membership is defined for selection of the optimum variant of the investment project by each criterion and each expert separately.

In the process of the expert questioning of the experts S_1, S_2, S_3, S_4, S_5 with the projects being compared p_1, p_2 by criteria $K_1, K_2, \ldots, K_{10}$, the linguistic theses are obtained which are evaluated by Saati scale and their quantitative estimate is found in the matrices of the paired comparisons below the main diagonal by each criterion separately. In the result of the calculations by the formulae 2–6, plotted membership functions of subnormal and normal fuzzy sets „ the most prioritized index of the investment project estimation" by each expert are built (Fig. 3–4).

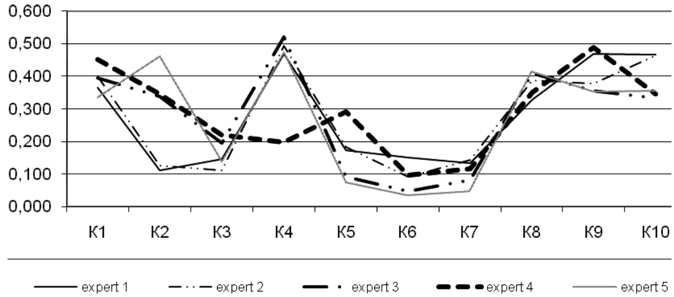

Fig. 3. Membership functions of the subnormal fuzzy set by the data of each expert

In the result of crossing fuzzy sets $\widetilde{K}_1 - \widetilde{K}_{10}$ of the priority estimation of each index of the investment project by an expert the following ranks of $K_1 - K_{10}$ criteria are obtained: α_1= 0.18; α_2= 0.06; α_3= 0.06; α_4= 0.10; α_5= 0.04; α_6= 0.02; α_7= 0.02; α_8= 0.18; α_9= 0.17; α_{10}= 0.16, which corresponds to the importance of the first, eighth, ninth and tenth criteria of estimation of the investment alternatives as compared with other indice.

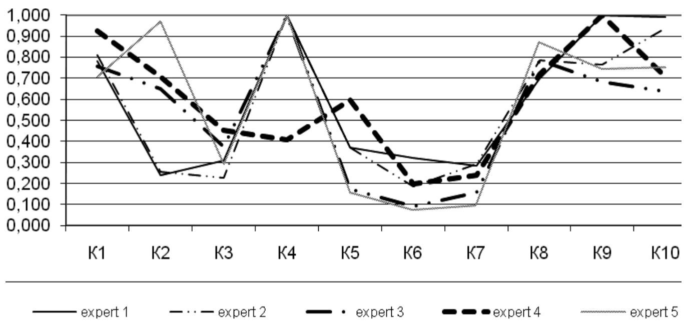

Fig. 4. Membership functions of the normal fuzzy set by the data of each expert

To confirm the possibility of using the results obtained for further reliable calculations it is necessary to check the matrices of paired comparisons for coordination. Under the coordination of the matrix is understood its cardinal coordination and transitivity. The coordination index is defined by the formula:

$$Ip = \frac{\lambda_{max} - n}{n-1}, \tag{7}$$

where n – an number of comparison elements; λ_{max} – maximum own value of the corresponding matrix of paired comparisons.

The coordination relationship:

$$Vp = \frac{Ip}{ch}, \tag{8}$$

where ch – a figure of random coordination (for the second order matrix it amounts to 0, for the tenth order matrix – 1,49).

The value Vp can be within 20%, and if these limits are not observed, an additional questioning of the experts is required to get the more precise estimates.

The analysis of the relationships obtained for each fuzzy set testifies to the reliability of the obtained output information. The coordination relationship in the analysis of the investment projects equals to zero which corroborates the maximum coordination level of the matrices of paired comparisons.

Further, by formula (10), the following fuzzy sets with an account of criteria ranks of estimation of the investment alternatives by each expert are calculated:

$$\widetilde{P}_1 = \left\{\frac{0.796}{p_1}, \frac{0.745}{p_2}\right\},\ \widetilde{P}_2 = \left\{\frac{0.817}{p_1}, \frac{0.7}{p_2}\right\},\ \widetilde{P}_3 = \left\{\frac{0.806}{p_1}, \frac{0.721}{p_2}\right\},\ \widetilde{P}_4 = \left\{\frac{0.816}{p_1}, \frac{0.767}{p_2}\right\},$$

$$\widetilde{P}_5 = \left\{\frac{0.806}{p_1}, \frac{0.79}{p_2}\right\}.$$

The final result of the priority of investment projects is defined by crossing the calculated fuzzy sets: $\widetilde{P}_{opt} = \left\{\frac{0.8}{p_1}; \frac{0.7}{p_2}\right\}$. The end data testify to the substantial advantages of the first project over the second one for taking the final investment decision.

CONCLUSIONS

Taking into account the fact of the investment strategy being encumbered with the risks of external and internal character, the risks that generalize the influence of irregularity of the production process through the state of unstable environment on the operation of an industrial enterprise equipments, it is expedient to apply the model of correcting the discounting rate when evaluating the effectiveness index of investments – the net present value. The proposed model forms a basis for a well-grounded decision concerning the choice of a strategic direction of the investment development of an enterprise taking onto account the production specific features of the enterprise and the state of the macro-environment.

To increase effectiveness of the methods proposed, it is operative to combine them with analysis of probabilistic distributions of the payment flows, with the methods of stochastic modeling and the models with fuzzy logic for the risk calculation of investment projects. The expediency of applying the fuzzy logic approach is conditioned by the following factors: first, the possibility of a choice multiplicity on the basis of quantitative calculations; second, a varied enumeration (list) of the quantitative analysis coefficients depending on the purpose of investing; third, imbalance of estimation criteria of investment alternatives depending on an expert's thought. The application of the given algorithm under the conditions of an industrial enterprise will allow to heighten the qualitative level of the managerial decision-taking in the sphere of investment-and-innovation strategy.

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