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INVESTMENTS PROJECTS EVALUATION BY USING FUZZY SET THEORY

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Introduction. Optimal investment project selection depends not only on the resulting index but on measures accuracy used for its calculating. Single sources of financing, risks quantitative indices, future flows of money, and market condition are difficult to define under unstable social-economic environment. We suggest applying fuzzy-set theory for partial considering discrepancies impact while defining the investment project indices. This allows us to determine investment project key measures range. One more advantage of applying this method is giving quantification to qualitative measures.

Recent research and publications review. American scientist Lofti A. Zadeh is the author of fuzzy-set theory [1, 2]. Among the foreign scientists whose works are devoted to the issues of investment projects financing and effectiveness evaluating applying fuzzy-set theory, the following are worth mentioning [3 – 6]. Native researchers have also paid attention to the issues in their works [7, 8].

Main tasks. The aim of the current research is developing algorithm for optimal investment project selection, taking into account not only traditional financial indices, but also financial risks and advantages.

Material and the results. Let us review the algorithm for investment project optimal structure and effectiveness with the help of the fuzzy-set theory on an example of investment-innovative project. Suppose of enterprise is considering possibility of three alternative investment-innovative projects implementation:

1. Constructing another facility for products manufacturing, applying process innovations.
2. New product type introduction that includes construction and technological equipment of an attached producing authority.
3. Integrative investment project including activities for raw materials quality improvement and increasing the products manufacturing amount.

For optimal project selection let us use both financial and nonfinancial criteria, and risks evaluating. We suggest choosing FNPV net discounted cost parameter as a financial criterion.

Projects net discounted cost is calculated by the equation

$$\text{FNPV}=\sum_{k=1}^{n}\frac{CF_k}{(1+r)^k}-\sum_{j=1}^{m}\frac{IC_j}{(1+i)^j}, \quad (1)$$

where CF_k is an income generated by investment is K year;

n – investment projects years number;

r – discount rate defined by a manager or an investor taking into account the desired income on the capital inversed.

IC – amount of the capital invested;

IC_j – investing during J year;

m – number of investing years;

i – average predicted rate of inflation.

As far as the projects being considered are only eligible for initial investing, the equation will be the following

$$\text{FNPV}=\sum_{k=1}^{n}\frac{CF_k}{(1+r)^k}-I_0, \quad (2)$$

where I_0 are initial investments.

External market environment dynamism and managers' limited ability to predict future money flows lead to the necessity of making decisions in a situation of uncertainty. Theoretical basis for making decisions in a situation of uncertainty is a fuzzy set theory, according to which investment project indices are reproduced by fuzzy numbers.

We consider CF_k, I_0 and r values to be trigonal fuzzy numbers (CFk1, CF_{k2}, CF_{k3}), (I_{01}, I_{02}, I_{03}) i (r_1, r_2, r_3) accordingly, then FNPV net discounted cost value is also a trigonal fuzzy number ($FNPV_1$, $FNPV_2$, $FNPV_3$), defined by an equation

$$(FNPV_1, FNPV_2, FNPV_3) = (\sum_{k=1}^{n} \frac{CF_{k1}}{(1+r_3)^k} - I_{03}, \sum_{k=1}^{n} \frac{CF_{k2}}{(1+r_2)^k} - I_{02}, \sum_{k=1}^{n} \frac{CF_{k3}}{(1+r_1)^k} - I_{01}) \ CF_{k1} \geq 0 \quad (3)$$

Membership function for FNPV is the following

$$\mu_{FNPV}(x) = \begin{cases} (x - FNPV_1)/(FNPV_2 - FNPV_1) \ FNPV_1 \leq x \leq FNPV_2 \\ (FNPV_3 - x)/(FNPV_3 - FNPV_2) \ FNPV_2 \leq x \leq FNPV_3 \\ 0 \ in \cdot other \cdot cases \end{cases} \quad (4)$$

Let us assume that investment project costs, amount of generated cash flows and discounting rate may vary up to 7% upward or downward.

Initial data of investment amount and generated money flows necessary for net discounted cost calculating of investment projects are given in table 1.

Table 1

Amount of investment projects money flow (in th hryvnias)

	Project 1			Project 2			Project 3		
C	(54457;	56142;	60072)	63193	65148	69708,	77392	79786	85371
CF_1	25620	27549	29477	26901	28926	30951	28182	30304	32425
CF_2	35709	38396	41084	37394	40316	43138	39279	42236	45193
CF_3	48103	51724	55345	50508	54310	58112	52914	56896	60879
CF_4	63372	68142	72912	66541	71549	76558	69710	74957	80204
CF_5	82218	88406	94595	86329	92827	99325	90440	97247	104054
CF_6	110368	118675	126983	115886	124609	133332	121405	130543	139681

Index of weighed average capital cost – 11,89%, with 7% acceptable deviation, is considered to be a discount rate, i.e. the discount rate is expressed by a fuzzy number (11,63; 11,89; 12,12).

The next step in calculating the value of FNPV investment projects net discounted cost by an equation (3), the data is given in table 2.

Table 2

Net discounted cost of innovative-investment projects

Project 1			Project 2			Project 3		
179256,1	190443,1	201618,9	180877,1	192511,2	2041639	176960,9	188677,5	200405,9

As it is clear from the calculating, the first innovative-investment project generates the biggest net money flow, and then comes the second project and the third one afterwards.

Non-financial criteria reflect investment projects important properties that can't be expressed through money flows. Expert estimation is used for their definition. The estimation results are reflected in the value of linguistic variables.

Let us identify nonfinancial advantages and projects risks. The list of non-financial advantages and risks is given in table 3.

Table 3

List of non-financial advantages and risks following the investment project

Nonfinancial advantages	Risks
Products quality increasing	Staff professional qualities
Increase of production	Technology reliability
Variety growth	Raw products provision
Raw products quality upgrading	Project underfunding
Seasoning factor evening-out	Financial sustainability loss risk
Raw products delivery	–

Nonfinancial project advantages are obtained directly while manufacturing products at the factory (three first advantages), and also at the cost of efficiency improvement in cooperation with raw products suppliers (the last three advantages).

Nonfinancial advantages and risks are of unequal importance for investment projects evaluating. With the purpose of expert estimation it is necessary to set a scale for defining importance of investment project advantages and risks listed above, that is to identify the value of linguistic variables reflecting importance either of these or other criteria. Penta-scale (five-level classification) chosen for this is shown in table 4.

Table 4

Scale of nonfinancial advantages and risks importance

Value	Symbol
Very important	VI (very important)
Important	I (important)
More-or-less important	MI (more-or-less important)
More-or-less unimportant	MU (more-or-less unimportant)
Unimportant	U (unimportant)

As a result of expert estimation, the following compatibility of values mentioned with project nonfinancial advantages and risks is identified (table 5).

Table 5

Importance of nonfinancial advantages and risks for investment projects assessment

Advantages and risks	Value
Nonfinancial advantages	
Products quality increasing	Very important
Increase of production	Very important
Variety growth	Very important
Raw products quality upgrading	Very important
Seasoning factor evening-out	Important
Raw products delivery	Relatively important
Risks	
Staff professional qualities	Relatively important
Raw products provision	Important
Technology reliability	Very important
Project underfunding	Very important
Financial sustainability loss risk	Relatively unimportant

For evaluating investment projects nonfinancial advantages and risks the following penta-scale is offered (table 5).

Table 6

Scale for evaluating nonfinancial advantages and risks

Value	Symbol
Nonfinancial advantages	
Very low	VL (Very low)
Low	L (Low)
Medium	M (Medium)
High	H (High)
Very high	VH (Very high)
Risks	
Very low	VL (Very low)
Low	L (Low)
Medium	M (Medium)
High	H (High)
Very high	VH (Very high)

As a result of expert estimation the following compatibility of values mentioned with project nonfinancial advantages and risks is identified (tables 7, 8).

Table 7

The list and linguistic values of investment projects nonfinancial advantages

Factors	Project 1	Project 2	Project 3
Products quality increasing	Very low	Very high	Very high
Increase of production	Medium	Medium	Very high
Variety growth	Low	Medium	Low
Raw products quality upgrading	Very high	Very high	Very high
Seasoning factor evening-out	Low	Medium	Very high
Raw products delivery	Low	Medium	Very high

Table 8

The list and linguistic values of investment projects nonfinancial risks

Factors	Project 1	Project 2	Project 3
Staff professional qualities	Medium	Very low	Very low
Raw products provision	High	Medium	Medium
Technology reliability	Low	High	High
Project underfunding	Low	Medium	Medium
Financial sustainability loss risk	Low	Medium	High

We suggest denoting (a_{ij1}, a_{ij2}, a_{ij3}) with a triangular fuzzy number reflecting advantages of i-th value of linguistic variables over j-th. There are equations $a_{iik} = 1$, where k=1,2,3, and $a_{ij1} = 1/a_{ji3}$, $a_{ij2} = 1/a_{ji2}$, $a_{ij3} = 1/a_{ji1}$.

To compare values of linguistic variable reflecting the importance of nonfinancial advantages and risks for investment projects evaluating the following triangular fuzzy numbers have been chosen.

$$\begin{pmatrix} (1,1,1) & (2,3,4) & (4,5,6) & (6,7,8) & (8,9,9) \\ \left(\frac{1}{4},\frac{1}{3},\frac{1}{2}\right) & (1,1,1) & (1,2,3) & (2,3,4) & (3,4,5) \\ \left(\frac{1}{6},\frac{1}{5},\frac{1}{4}\right) & \left(\frac{1}{3},\frac{1}{2},1\right) & (1,1,1) & \left(1,\frac{3}{2},2\right) & \left(\frac{3}{2},2,3\right) \\ \left(\frac{1}{8},\frac{1}{7},\frac{1}{6}\right) & \left(\frac{1}{4},\frac{1}{3},\frac{1}{2}\right) & \left(\frac{1}{2},\frac{2}{3},1\right) & (1,1,1) & \left(1,\frac{5}{4},\frac{3}{2}\right) \\ \left(\frac{1}{9},\frac{1}{9},\frac{1}{8}\right) & \left(\frac{1}{5},\frac{1}{4},\frac{1}{3}\right) & \left(\frac{1}{3},\frac{1}{2},\frac{2}{3}\right) & \left(\frac{2}{3},\frac{4}{5},1\right) & (1,1,1) \end{pmatrix} \quad (5)$$

This matrix lines and columns correspond to the values of linguistic variable, shown in table 3.10. Let us define geometric means of triangular fuzzy numbers of advantages matrix. For the i-th line geometric mean is defined with an equation

$$Q_i = (q_{i1}, q_{i2}, q_{i3}) = \left(\sqrt[n]{\prod_{j=1}^{n} a_{ij1}}, \sqrt[n]{\prod_{j=1}^{n} a_{ij2}}, \sqrt[n]{\prod_{j=1}^{n} a_{ij3}} \right) \quad (6)$$

The importance of i-th value of linguistic variable is defined from the equation

$$W_i = (w_{i1}, w_{i2}, w_{i3}) = \left(\frac{q_{i1}}{\sum_{i=1}^{n} q_{i3}}, \frac{q_{i2}}{\sum_{i=1}^{n} q_{i2}}, \frac{q_{i3}}{\sum_{i=1}^{n} q_{i1}} \right). \quad (7)$$

The values of linguistic variables reflecting investment projects nonfinancial advantages and risks level estimation are defined in the same way.

Thus, we have defined explication of linguistic scale for linguistic variables reflecting criteria importance, nonfinancial advantages values and risks value. This explication is presented in table 9.

Table 9

Linguistic scale explication

Fuzzy numbers	Criteria importance	Nonfinancial advantages value	Risks value
(0,04; 0,06; 0,08)	Unimportant	Very low	Very high
(0,09; 0,13; 0,20)	Relatively unimportant	Low	High
(0,16; 0,24; 0,39)	Relatively important	Medium	Medium
(0,29; 0,45; 0,73)	Important	High	Low
(0,667; 1,00; 1,00)	Very important	Very high	Very low

Nonfinancial advantages of k-th project are marked as $NFMA_k$ and calculated from an equation:

$$NFMA_k = (W_{k1}, W_{k2}, W_{k3}) = \left(\left[\frac{\sum_{i=1}^{n} V_{i1} G_{ik1}}{n} \right], \left[\frac{\sum_{i=1}^{n} V_{i2} G_{ik2}}{n} \right], \left[\frac{\sum_{i=1}^{n} V_{i3} G_{ik3}}{n} \right] \right) \quad (8)$$

where n is a number of nonfinancial advantages;

(V_{i1}, V_{i2}, V_{i3}) – a fuzzy number defining importance of i-th criterion;

(G_{ik1}, G_{ik2}, G_{ik3}) – a fuzzy number defining the value of i-th criterion for k-th investment project.

Accordingly we mark nonfinancial risks of k-th project as RMA_k and calculate from an equation

$$RMA_k = (RMA_{k1}, RMA_{k2}, RMA_{k3}) = \left(\left[\frac{\sum_{i=1}^{n} V_{i1} R_{ik1}}{n} \right], \left[\frac{\sum_{i=1}^{n} V_{i2} R_{ik2}}{n} \right], \left[\frac{\sum_{i=1}^{n} V_{i3} R_{ik3}}{n} \right] \right), \quad (9)$$

where n is a number of risks;

(V_{i1}, V_{i2}, V_{i3}) – a fuzzy number defining the importance of i-th risks types;

$(R_{ik1}, R_{ik2}, R_{ik3})$ – a fuzzy number defining the value of i-th risk for k-th investment project.

Therefore projects both nonfinancial advantages

Project 1	Project 2	Project 3
0,1132 0,2526 0,3157	0,1960 0,4407 0,5347	0,2821 0,6367 0,7195

and risks are defined with fuzzy numbers.

Project 1	Project 2	Project 3
0,0641 0,1500 0,2931	0,0603 0,1347 0,2309	0,0592 0,1323 0,2246

We suggest decide on the best project on the basis of projects financial advantages, nonfinancial advantages and risks

$$RV(A_k) = (FMA_{k2})\{(O)[(FMA_{k3}-x_{min}) / (x_{max} - x_{min}+FMA_{k3} - FMA_{k2}) +$$
$$+(1 - O)(1 – (x_{max} - FMA_{k1}-) / (x_{max} - x_{min}+FMA_{k2} - FMA_{k1})]\}$$

where

$$x_{max} = \sup S, \quad x_{min} = \inf S, \quad S = \bigcup_{k=1}^{q} S_k,$$
$$S_k = \{FMA_{k1}, FMA_{k2}, FMA_{k3} \mid k=1,2,3,\ldots q\}$$

O is Hurwicz coefficient (0<O<1), that reflects managers' optimism-pessimism level, where 0 is used for complete optimism, and 1shows manager's complete pessimism as for the situation development. We accept O=0,5 for calculations.

Resulting indices of the investigated investment-innovative projects indicators are presented in table 10.

Table 10

Indicators of investigated investment-innovative projects

	Financial advantages	Nonfinancial advantages	Risks
Project 1	0,66	0,03	0,20
Project 2	0,29	0,34	0,12
Project 3	0,25	0,63	0,68

According to the calculations performed, the first investment-innovative project is characterized by the biggest net discounted value and moderate risk, although it provides the smallest number of nonfinancial advantages. The second investment project is characterized by the least risk and has moderate net discounted value, and provides nonfinancial advantages. The third investment project is the most risky one although provides the biggest nonfinancial advantages, and is characterized by the least net discounted value of all the projects compared.

We suggest enterprise financial managers making the final decision, since they are aware of both official and insider information.

Conclusions. Using of the proposed model will allow lessening the uncertainty factor while calculating investment project parameters (its amount, raised capital cost, discount rate etc.); including into calculation such parameters as obtaining nonfinancial advantages and investment project risks; selecting optimal investment project on the basis of reduced to one numerical index data of investing, capital cost, risks occurring while its implementing, getting nonfinancial advantages. –

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Hanna Kornyliuk, PhD (Finance), Senior Lecturer. Kyiv National Economic Vadym Hetman University – Research University. **Investments projects evaluation by using fuzzy set theory.** The aspects of evaluation and selection of the investment projects under conditions of uncertainty are considered. The usage of fuzzy set theory for selection of the investment projects is proposed. The advantage of this approach is the ability to project evaluation, taking into account possible changes in key indicators of the project. Also, in addition to using the traditional criterion of the efficiency of the investment project (NPV) is proposed to use such factors as non-financial risks and non-financial benefits. The use of such a model will more clearly define the optimal investment project not only on financial performance, but also taking into account non-financial criteria.
Keywords: investment project, fuzzy set theory, linguistic variable.

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Анна Валентинівна Корнилюк, кандидат економічних наук, старший викладач. ДВНЗ «Київський національний економічний університет імені В. Гетьмана». **Використання теорії нечітких множин для оцінювання ефективності інвестиційних проектів.** Розглянуто питання вибору оптимального інвестиційного проекту на основі традиційних фінансових критеріїв, а також нефінансових показників: нефінансових ризиків та переваг.
Ключові слова: інвестиційний проект, теорія нечітких множин, лінгвістичні змінні.

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Анна Валентиновна Корнилюк, кандидат экономических наук, старший преподаватель. ГВУЗ «Киевский национальный экономический университет имени В. Гетьмана». **Использование теории нечетких множеств для оценки эффективности инвестиционных проектов.** Рассмотрены вопросы выбора оптимального инвестиционного проекта на основе не только традиционных финансовых критериев, но и нефинансовых показателей: нефинансовых рисков и преимуществ.
Ключевые слова: инвестиционных проект, теория нечетких множеств, лингвистические переменные.