# 1.5 Modeling of enterprise investment activity, taking into account an environmental factor

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**Abstract**

The modern economy is becoming more dependent of environmental standards and orientation on international concept of sustainable development.

The most important condition on the way of economy transition to an innovative way of development is preservation of human vital activity-environment system equilibrium. Significant role in achievement of the country's economy strategic objectives performs investment activities, which affects not only the conditions of human vital activity, but also on the ecologo-economic system state.

At the paper, necessity to taking into account an environmental factor in the process of investment projects estimation is defined.

The projects efficiency criteria are suggested to calculate using the elements of the fuzzy sets theory, by mean of which many uncertainties factors may be formalized and correctly considered in the estimation process. The approach promotes objective justification of the investment decision.

**Keywords**

Fuzzy set, ecologo-economic estimation, investment project, sustainable development.

## 1. INTRODUCTION

One of the most pressing challenges on the way to sustainable manufacturing is necessity to improve of the enterprises investment activity, taking into account environmental aspects.

At a market economy conditions in the enterprise investment activities management system must be considered a complex of factors that influence the decision on the amount and structure of capital investments.

Consider the features of the enterprises investment activity improvement in the direction of strengthening its orientation to the solution of environmental problems.

## 2. ENVIRONMENTAL FACTOR IN ECONOMY

### 2.1 Economic factor of ecological information

Consider the generalized index, which would reflect the economic importance of ecological information [2, p. 54; 7, p. 56-57].

Assume $I_t$ - volume of ecological information, which can be objectively received at the $t$ moment of time, and $I_u$ - the volume of this information, used in national economy. Then the relation of $K_{ec} = I_u/I_t$ represents the demand coefficient of ecological information.

On the fig. 1 qualitative dependence of $K_{ec}$ from one of the most important economic indicators –gross domestic product per capita is shown ($GDP/N_p$, $N_p$ - population size).

$K_{ec}$ increases at growth of specific GDP, i.e. growth of society welfare is inevitably connected with increase of the ecological information weight, used in national economy. Two conclusions can be done.

First of all, there is inverse monotonously increasing functional dependence of GDP per capita on the economy's demand for $K_{ec}$ ecological information (fig. 2) owing to the $K_{ec}$ function monotonicity.

It means that the GDP growth is directly connected with improvement of society activity conditions and environment.

Secondly, ecological information starts to play an appreciable role as object and an element of information business only from a certain stage of the country economic development.

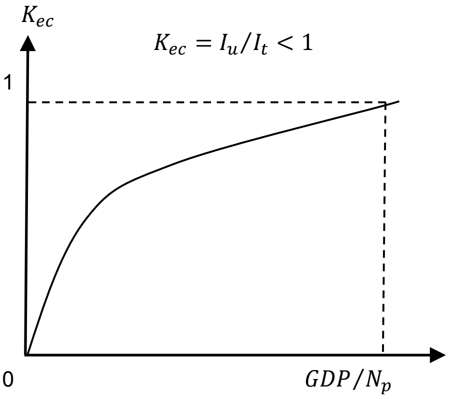


Figure 1: Qualitative dependence of $K_{ec}$ from GDP per capita.

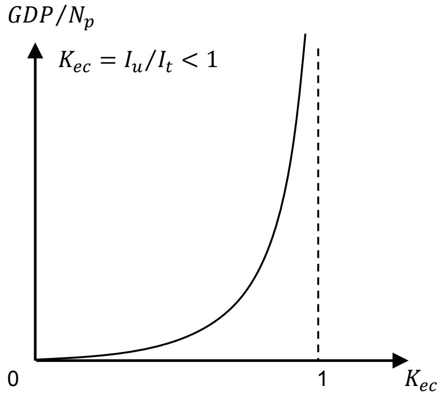


Figure 2: Functional dependence of GDP per capita on the economy demand for $K_{ec}$ ecological information.

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**2.2 Database of ecological information**

The scheme of a two-level database of ecological information is shown on fig. 3 [2, p. 51].

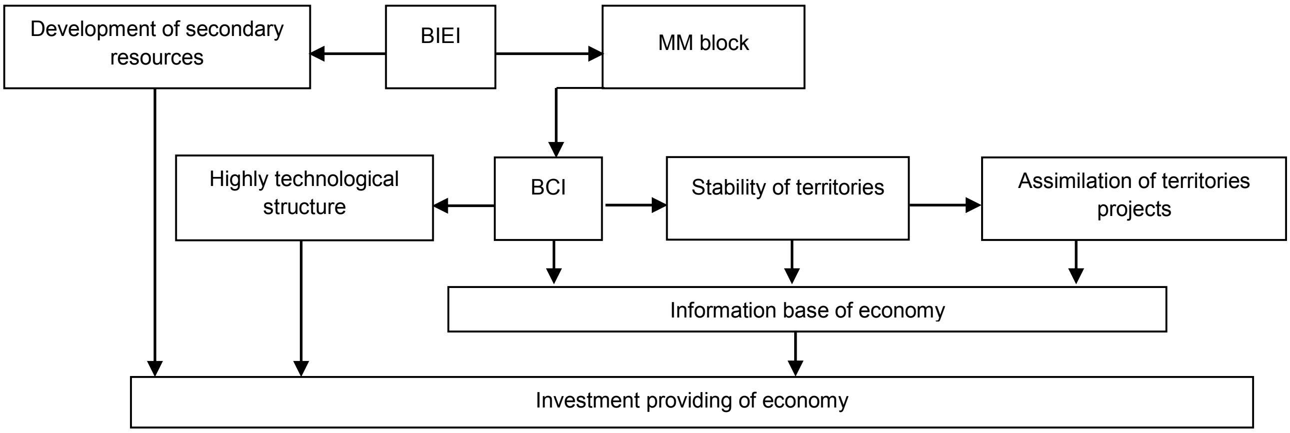


Figure 3: Two-level database of ecological information.

Information should be prepared and adapted for use in the corresponding mathematical models of ecologo-economic systems. Should be two interconnected levels:

- primary ecological information on a natural and technogenic situation of territories (base of initial ecological information – BIEI). It also includes information about the limits of specific locations environmental sustainability in the most characteristic of them natural processes;
- such database, tariffing the regions, with participates in the micro economical communications, as objects of possible technological development with a certain framework (base of calculating information – BCI) created on the first level ecological information basis through the math models (MM) complex.

**2.3 Management of environment**

The environment management efficiency depends of the enterprise readiness to conduct systematic management of environment.

The enterprise, which control system includes management of environment, possesses a basis for a balancing of economic and ecological interests and can reach considerable advantages in the competition. The potential benefits connected with effective management of environment, include:

- support from the state and the public;
- satisfaction to ecological requirements of investors and expansion of access to the capital;
- improvement of reputation and increase in a market share.

The model of enterprise environment control system is presented on the fig. 4 [1]:

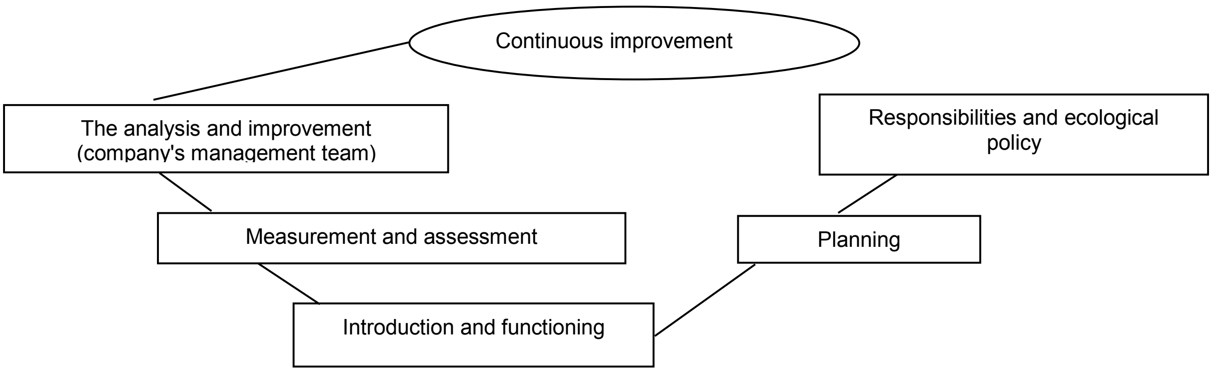


Figure 4: Model of environment control system.

The model consists of the following basic elements:

1. *Ecological policy.* The enterprise should define the ecological policy and incur responsibilities concerning management of environment.
2. *Planning.* The enterprises should create the plan of the ecological policy realization.
3. *Introduction.* The enterprise should create possibilities and the mechanisms, necessary for implementation of their ecological policy and achievement of planned ecological indicators.
4. *Measurement and assessment.* The enterprise should measure, supervise and estimate the ecological efficiency.
5. *Analysis and improvement.* The enterprise should analyze and constantly improve the environment control system.

### 3. COMPLEX APPROACH TO INVESTMENT PROJECTS EVALUATION

At the market economy conditions in the management of enterprise investment activity should be considered a complex system of factors, influencing to decision on the amount and structure of capital investments. Among the many factors, defining of the company investment strategy, the main are economic and financial, sociopolitical and legal, and environmental factors too [3, p.82].

There are the following reasons of environmental factors consideration in the evaluation of investment projects:

- ✓ complexity of many factors impact on the environment accounting due to their diversity;
- ✓ absence of methods that allow to give a complex evaluation of the investment projects efficiency;
- ✓ weak institutionalization of relations in the sphere of compensation for damage, caused to the environment.

These circumstances cause necessity of ecologo-economic evaluation of investment projects methodology development.

Such assessment would allow to determine project performance indicators and to draw conclusions about its desirability and feasibility by means of calculation consequences of impact on the environment in monetary terms.

Use of this methodology will allow to evaluate and grade the investment projects, depending on the environmental equilibrium level and economic efficiency.

At the fig. 5 algorithm of the investment projects ecologo-economic evaluation is shown.

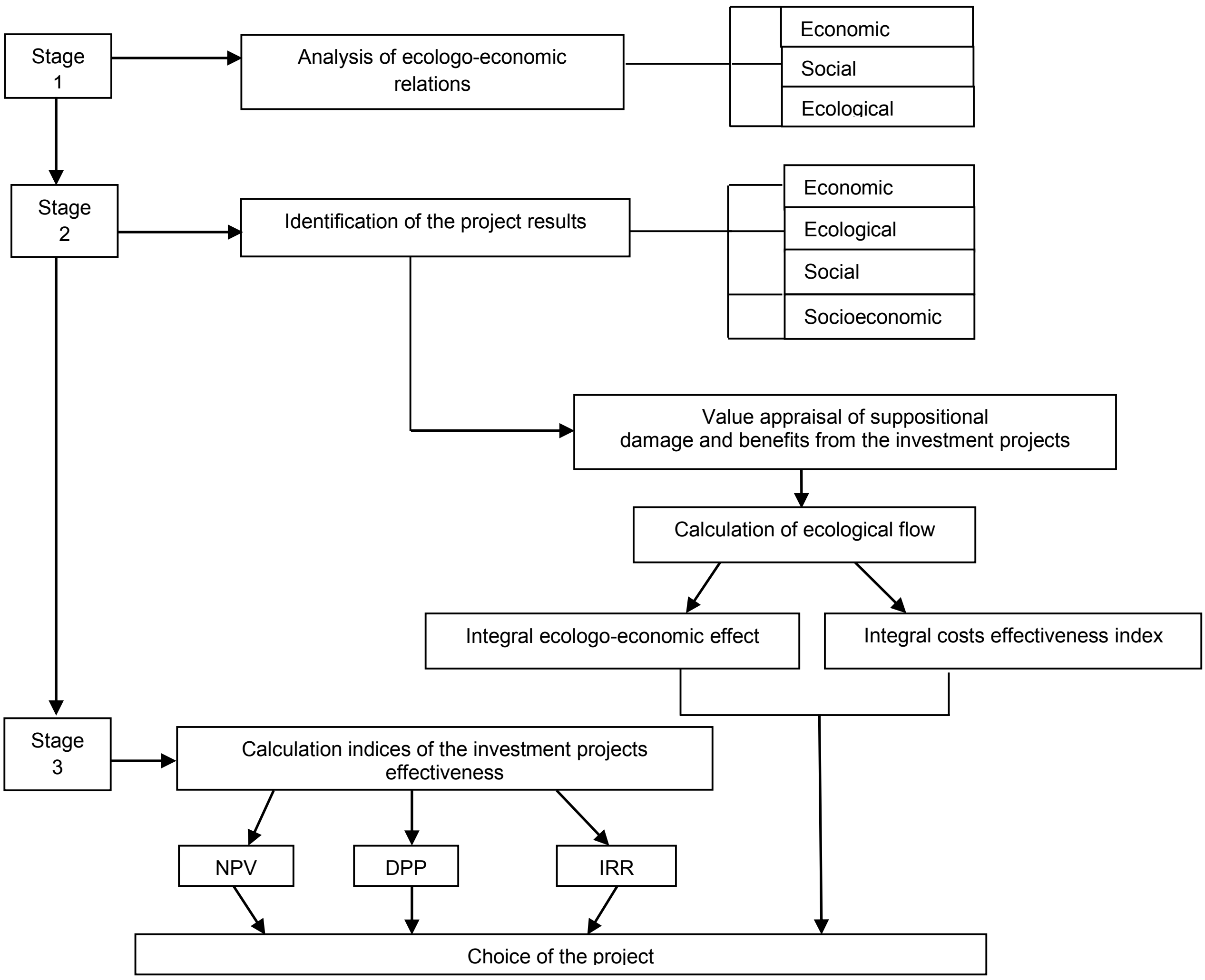


Figure 5: The algorithm of the investment projects ecologo-economic evaluation

### 3.1 Valuation of suppositional damage and benefits from the investment projects realization

Consider in more detail the second stage of algorithm. After identification of the projects results, valuation of suppositional damage and benefits is carried out.

Understanding of the project ecological component valuation is based on the components such as operating and investing activities. Because investments on implementation of environmental protection - is an element of a cash flow from investing activities, and operating costs of environmental protection equipment - an element of a cash flow from operating activities.

Accumulation in one cash flow of environmental support of the project costs, and then defining environmental impacts, both positive and negative, in value terms, will allow [5, p. 64-72]:

- ✓ identify the dependence between the ecological costs volume and volume of ecological results;
- ✓ determine the optimal level of said indicators ratios to achieve adequate level of the project environmental safety;
- ✓ determine integral indicators of the ecological costs efficacy.

Consider the method of investment project ecological flow calculation [5, c. 64-72].

Ecological flow value is calculated as:

$$F_t^e = I_t^e - O_t^e, \qquad (1)$$

where $I_t^e$ is environmental component of cash inflow;

$O_t^{Э}$ is cash outflow;

$t$ is a step number of calculation, which takes values from 0 to $T$.

The positive impact of the project on the environment contributes to following benefits ($B_t^e$):

- ✓ production output is increased due to development of the recycling of wastes system;
- ✓ the market of environmental works and services is expanding;
- ✓ investment prospects of the region or industry is increased.

We can distinguish the investment and operating costs for the environmental character measures implementation by means of the cash outflows $O_t^{Э}$ environmental component consideration.

A conditionally suppositional damage valuation $D^{CAD}$ is accepted as a value of the ill environmental effect.

*Conditionally suppositional damage* - is the valuation of potential losses and negative changes in the environment due to investment project implementation.

Depending on the loss wording and the object influence characteristics, it can be identified economic, ecological, social and socioeconomic investment project implications.

Thus, the conditionally suppositional damage can be divided into economic, ecological, social and socioeconomic.

*Conditionally suppositional economic damage* $D^{CAE}$ - is the loss of products, services, equipment, fuel, energy, raw materials and other materials as a result of waste and irrational resources use.

*Conditionally suppositional ecological damage* $D^{CAECO}$ - refers to a state of ecological systems and natural resources.

*Conditionally suppositional social damage* $D^{CAS}$ – represents increase of psychological stress on the population; decrease in length and quality of life.

*Conditionally suppositional socioeconomic damage* $D^{CASE}$ - is the costs for social security and health care, due to increasing incidence as result of environmental pollution.

To determine the social losses the most effective approach the expert evaluations method is used. Experts are asked to estimate the social losses coefficient $K^{SL}$, which ranges from 1 to 2:

- ✓ 1 – the factor is insignificant for social repercussions of the project;
- ✓ 1,25 – the factor is inessential for social repercussions of the project;
- ✓ 1,5 – expert can't say anything definite about impact of the factor;
- ✓ 1,75 – the factor is essential for social repercussions of the project;
- ✓ 2 – the factor value is obvious and is very essential for social repercussions of the project.

Social losses coefficient $K^{SL}$ is determined by the formula:

$$K^{SL} = \frac{\sum_{m=1}^{M} P_{im}}{M}, \qquad (2)$$

where $P_{im}$ is estimation of *i*-th factor value by expert *m*; *M* is number of experts.

*Total value of conditionally suppositional damage* caused by the investment project can be represented as follow:

$$D^{CAD} = (D^{CAE}) + (D^{CAECO}) + (D^{CASE})K^{SL}. \qquad (3)$$

$D^{CAD}$ value should not exceed the conditionally suppositional normative damage ($D^{CAD,norm}$), which is calculated in compliance with normative indicators of environmental quality. To account for the ratio of normative and conditionally suppositional damage in the investment project effectiveness evaluation should be calculated eco-index of the project:

$$I_t^{ECO} = \frac{D_t^{CAD}}{У_t^{CAD,norm}}. \qquad (4)$$

If the eco-index value is greater than 1, it means the permitted damages are exceeded. Taking into account (4) eco-flow model can be represented as:

$$F_t^E = I_t^E - O_t^E = B_t^E - [D_t^{CAD} + O_t^E I_t^{ECO}]. \qquad (5)$$

Now one can calculate the key efficiency indicators of the investment project, based on the cash flow from investment ($F^{IV}$), operating ($F^O$) activity and eco-flow ($F^E$), consisting in return, of the project cash inflows ($I^{IV}$), ($I^O$), ($I^E$) and outflows ($O^{IV}$), ($O^O$), ($O^E$).

*Integral ecologo-economic effect* calculated by the formula:

$$E^{IEE} = K^{SL} \sum_0^T \frac{F_t^{IV} + F_t^O + F_t^E}{(1+E)^t}, \qquad (6)$$

where *E* is the discount rate. The project will be considered effective if $E^{IEE}$ is a positive [5, p. 64-72].

*Integral costs effectiveness index:*

$$I^{IEC} = K^{SL} \frac{\sum_0^T (I_t^{IV} + I_t^O + I_t^E)}{\sum_0^T (O_t^{IV} + O_t^O + O_t^E)} \qquad (7)$$

*The criterion of cost effectiveness is the ratio:*

$$I^{IEC} > 1 \qquad (8)$$

### 3.2 Indices of the investment projects effectiveness

Third stage of the algorithm (fig. 5) involves the calculation of indices of the investment projects effectiveness. Companies must evaluate a potential projects maximal qualitative and in a short time at the estimation and choice of the investment projects process. As a rule, the degree of this projects elaboration is very low and therefore, there is limited, inaccurate and incomplete information for them. In such circumstances, it is difficult and inappropriately to use of standard approaches to the projects evaluation, due to lack of information.

In such situation, the most effective is use fuzzy sets theory elements, through which many uncertainties factors may be formalized and properly taken into account [6, p. 559–563]. The fuzzy-multiple methods significant advantages include the possibility of uncertainty accounting not only during the efficiency calculation, but also in the cash flow of the project forming process.

The obvious advantages of the fuzzy sets methods include:

- ✓ the possibility of formalizing the many uncertainties factors, that described by natural language;
- ✓ no requirement to gleichheit form of the membership functions;
- ✓ unlimited number of scenarios for the project development;
- ✓ tools to reduce subjectivity of the expert estimates.

The possibility of using information in the fuzzy form at the investment projects analysis and the construction on the basis of a cash flow provides wide range of information for analysis of the project attractiveness to researcher.

Generally accepted indices of the investment projects effectiveness (*NPV*, *DPP*, *IRR*) need to calculated under condition, that cash flows has a fuzzy form for objective substantiation of the investment decision. And for the most complete analysis it is necessary to present the indices in the crisp and fuzzy form. Consider the methods of *NPV*, *DPP* and *IRR* calculating for the case, when fuzziness of the project parameters is modeled with standard membership functions.

If cash flows represent a fuzzy numbers *net present value* is calculated by the formula:

$$\overline{\overline{NPV}} = \sum_{t=1}^{n} \frac{\overline{\overline{In_t}} - \overline{\overline{Out_t}}}{(1+r)^t}, \quad (9)$$

where $t = 1,2,\dots,n$ is number of periods; $\overline{\overline{In_t}}$, $\overline{\overline{Out_t}}$ are volumes of revenues and expenses respectively presented in the form of fuzzy numbers; $r$ is discount rate (crisp number).

If cash flow components has a membership function standard form, $\overline{\overline{NPV}}$ will also be in the form of fuzzy numbers, because addition, subtraction of fuzzy numbers and dividing by the crisp number does not change the original form of fuzzy numbers.

Also if the discount rate consider as a fuzzy number, the division of fuzzy numbers result does not retain the original standard form. If the discount rate is low, it's possible values dispersion is also small; then the membership function curvature of a fuzzy $\overline{\overline{NPV}}$ is negligible and can be ignored.

Determination of *the internal rate of return* in the classical formulation is to solve for the unknown variable *IRR* equation:

$$\sum_{t=1}^{n} \frac{\overline{\overline{In_t}} - \overline{\overline{Out_t}}}{(1+IRR)^t} = 0. \quad (10)$$

The left-hand side of equation (10) is an fuzzy number, and the right is the crisp number of zero. To be able to correctly perform mathematical operations at the indicator calculation process it is necessary to transform the equation so that right and left sides were agreed.

- ✓ One option is to change the form of the right part, which can be interpreted as a fuzzy zero. This fuzzy zero is characterized in that the maximum degree of membership to this fuzzy number should be zero for crisp number.

*Convex fuzzy number A, the base of which is a set of real numbers X, called fuzzy zero if*

$$\mu_A(0) = \sup_x(\mu_A(x)). \quad (11)$$

The value of *IRR*, found in the equation (10), can be interpreted as the discount rate at which net present value equal to fuzzy number; the membership function of this fuzzy number reaches a maximum – 1 in a zero number. This approach is easy to use and single-digit in cases, where the triangular fuzzy numbers is operating. If the fuzzy numbers involved at the calculations are complex form, it is supposed to use the second method for calculating the index.

- ✓ The second way is backward transformation - bringing to the crisp form the left side of equation:

$$defuzz\left(\sum_{t=1}^{n} \frac{\overline{\overline{In_t}} - \overline{\overline{Out_t}}}{(1+IRR)^t}\right) = 0, \quad (12)$$

where $defuzz(\cdot)$ is one of the functions that allow compare of the argument crisp value of its value represented by fuzzy number. If cash flows are expressed in fuzzy numbers of standard form, the equation can be solved explicitly. When cash flows are arbitrary fuzzy form, *IRR* is calculated by the exhaustive search of the desired parameter values until is equality in the equation, with a required accuracy, is reached. Calculation effectively carried out using of Matlab software environment.

Thus, the general equation with respect to $\overline{\overline{IRR}}$:

$$defuzz\left(\sum_{t=1}^{n} \frac{\overline{\overline{In_t}} - \overline{\overline{Out_t}}}{(1+\overline{\overline{IRR}})^t}\right) = 0 \quad (13)$$

may have more than one solution, and analyst needs an additional condition for the final selection. Such condition can be the function value, which consists of two components, that characterize $\overline{\overline{IRR}}$ fuzzy value. The first component is a defuzzification value of $\overline{\overline{IRR}}$: $defuzz(\overline{\overline{IRR}})$.

This value should be minimized, which corresponds to the classical case of $IRR$ precise meaning estimation, when there is more than one solution of equation (1), from which the minimum value of $IRR$ selected. The second part of the function represented by the component, which formalize a fuzzy set fuzziness measure. Fuzziness measure can be defined as a distance from the fuzzy set $A$ to the nearest crisp set $A_0$.

*A crisp set, nearest to the fuzzy set $A$ with membership function $\mu_A(u) (u \in U)$, is a subset $A_0$ of the set $U$, whose characteristic function is determined by the formula* [4, p. 26]:

$$\mu_{A_0} = \begin{cases} 1, if\ \mu_A > 0{,}5; \\ 0, if\ \mu_A < 0{,}5; \\ 1\ or\ 0, if\ \ \mu_A = 0{,}5 \end{cases}. \quad (14)$$

A fuzziness measure can be formalized in the functional form described by the formula, using the Hamming distance:

$$\text{fuzziness(A)} = \int_E |\mu_A(x) - \mu_{A_0}(x)| dx. \quad (15)$$

For the fulfillment of the $0 \le fuzziness(A) \le 1$ condition, the above expression must be divided by the $1/2 \int_E dx$. A fuzziness measure of the required internal rate of return - $fuzziness(\overline{\overline{IRR}})$ should be minimal. Therefore, the second component of the function, requiring of minimization, can be represented by the following formula:

$$\text{fuzziness}(\overline{\overline{\text{IRR}}}) = \int_{\text{R}} \left| \mu_{\overline{\overline{\text{IRR}}}}(\text{x}) - \mu_{\overline{\overline{\text{IRR}}}_0}(\text{x}) \right| \text{dx}. \quad (16)$$

The *discounted payback period* $DPP$ is the final form of the function, which should be minimized:

$$fuzziness(\overline{\overline{IRR}}) + defuzz(\overline{\overline{IRR}}) \to min. \quad (17)$$

There are two methods of the payback period calculating.

- ✓ Under the first method, the crisp form $DPP$ for the net cash flow can be determined, based on the comparison of fuzzy numbers method, with using membership function defuzzification value. According to this method, the formula for $DPP$ determining in the case when all the parameters of the project are specified in the fuzzy form, takes the following form:

  $$defuzz\left(\sum_{t=1}^{DPP} \frac{\overline{\overline{In_t}} - \overline{\overline{Out_t}}}{(1+\overline{\overline{r}})^t}\right) = 0, \quad (18)$$

  where $DPP$ is discounted payback period; $defuzz(\cdot)$ is defuzzification function.
- ✓ The second method is constructed on the fuzzy numbers principles of ordering, based on fuzzy relations. Comparison of the $defuzz(\cdot)$ function argument fuzzy values from the left side of (18) with zero can be achieved by comparison of fuzzy numbers. One way is to compare the membership functions maximum values, corresponding to the different variants of $\overline{\overline{NPV}}(DPP)$ fuzzy values mutual relations under different $DPP$ and zero values.

The above methods of the investment projects effectiveness estimation in the form of fuzzy numbers allow to valuate the projects comprehensively with a high degree of information uncertainty about the project implementation.

## 4. SUMMARY

So, according to the proposed method of ecologo-economic evaluation, based on the investment projects effectiveness indices (*NPV, DPP, IRR*) and also valuation of suppositional damage and benefits from the investment projects realization integral ecologo-economic effect and integral costs effectiveness index selects the investment project.

Thus, the ecologo-economic evaluation of the project is an important investment designing tool.

Businessmen and the government should provide sustainable, environmentally acceptable development by limiting or even eliminating of the investment projects negative impact on the economy, ecology and population by implementing such assessment.

Thus, the problem of improvement the enterprise investment activities, taking into account an environmental factor, should be tackled on a joint of investment management problem and economic aspects of environmental problems, using mathematical models

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