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Environmental and Economic Evaluation of the Investment Projects Basing on Fuzzy Sets Theory

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One of the most important challenges on the way to sustainable manufacturing is necessity to improve of the enterprises investment activity, taking into account environmental aspects. The main purpose of the paper is development of mathematical models and methods for the investment projects estimation, taking into account the various aspects of implementation, in the conditions of stochastic uncertainty.At the paper method of environmental and economic evaluation of the investment projects, which help to draw conclusions about the projects feasibility is proposed. The indices of investment projects effectiveness 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 proposed complex estimation of the project promotes objective justification of the investment decision and increased the accuracy of the project evaluation on 25% compared with traditional methods.

JEL Codes: C02, C81 and Q01.

1. Introduction

The current state of industry development is characterized that along with the problems of product promotion and improve of production competitiveness, related to the investments, increasing attention is drawn on an environmental condition of regions, where the industrial enterprises are concentrated.

Enterprises do not pay attention to the gas burst cleaning, discharges to water sources and also recycling of wastes. Applied administrative and economic methods to increase of the enterprises responsibility for environment protection do not give the desirable results. Based on the socioeconomic reasons, such as the desire to reduce the cost loading of producers and strengthen their position at the international markets, unfortunately, the legislation of some countries do not provide full losses compensation, suffered by companies fault.

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 also environmental factors.

As seen in fig. 3 in appendix, most of the companies in the Russian Federation show only a formal compliance to the environmental standards. The initiative is to prevent pollution and cleaner production is showing only a few companies.

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The figure shows the percentage correlation of the enterprises types according to the environmental factors accounting in their management systems.

There are the following reasons of environmental factors consideration in the evaluation of investment projects (Krass 2012):

- 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 environmental and economic evaluation of investment projects methodology development.

Such innovative approach to investment projects assessment, different from traditional methods, 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.

The following section provides literature review. In paragraph 3 environmental and economic evaluation of the investment projects methodology is represented. Namely, the uncertainty, associated with the investment projects implementation (3.1) and structure of the enterprise total costs resulting deterioration of the environment quality (3.2). In the next paragraphs is considered the algorithm of the methodology (3.3), valuation of suppositional damage and benefits from the investment projects realization (3.4) and also indices of the investment projects effectiveness (3.5).

In paragraph 4 represented the findings and paragraph 5 made the main summary and conclusions. Then references and appendix is followed.

2. Literature Review

Investments are the important part of enterprises activities, experience of the functioning of which suggests, that the choice of the investment project for funding in the conditions of uncertainty caused by the economic environment instability, currency fluctuations, market situation and also inflation remains open. Zaboev (2008) described various types of uncertainty, at which investment project is carried out.

Tikhomirov, Potravny, Tikhomirova (2003) and also Nuzhina (2010) underscored the importance of environmental factors at the enterprise management system. They proposed the methodology of the environmental and economic risk analysis and management.

Speaking of traditional approaches of the investment projects estimation, there are significantly more problem statements in the modern practice of investing, than offered solutions in the theory of investment analysis. Authoritative specialist professor T. Copeland (2010) underscored a number of shortcomings of the NPV method. The main shortcoming of the method is the lack of flexibility and the inability to complete analysis of all investment project scenarios.

Many uncertainty factors and shortcomings of traditional methods can be formalized and correctly taken into account in the investment project evaluation by means of the fuzzy sets theory. Subjectiveness of the expert estimates can be significantly reduced through the methods based on fuzzy sets theory, such as the interval method. This method has been successfully used in cases when boundaries, within the analyzed parameters can vary, is known, but the distribution of likelihood within the interval is unknown.

3. Environmental and Economic Evaluation of the Investment Projects

In order to analyze the situation of the environmental factors accounting at the investment projects estimation were considered 15 Russian companies activities for the period from 2009 to 2013 years.

3.1 The Uncertainty Associated With the Investment Projects Implementation

Feature of enterprises related to the investment projects implementation is the uncertainty. As a rule, uncertainty can be caused by incomplete or inaccurate information on (Nujina 2010):

- The possibility of adverse events, its development peculiarity, the expected effect;
- The apprehended damage structure caused by this event and its magnitude for each component of the structure;
- The impact of protective measures and other factors on the likely damage magnitude.

Uncertainty also affects the reliability results of every step of the risk analysis and validity of the resulting conclusions. Due to incorrect conclusions and decisions, the effectiveness of the measures to protect and management of risk are reduced, and the total costs of enterprises, carrying out of investment activity in the condition of risk are increased. Costs can grow because of risk underestimation (strength of adverse events), and also by repricing of risk.

Consider the main types of uncertainty and associated risks that may arise in the investment projects implementation (Zaboev 2008).

Table 1: Types of uncertainty

Type of uncertainty	Description	Risks
Zero degree	Strict determinancy of the situation and the process determines the choice of solutions based on direct calculations of different options efficiency.	-
Quasi - determinancy	Development of situation and processes are monitored, but the timing of events, their force defined in some ranges.	Inconsistencies of predictive value of expected damage and actual values at security policies different types.
Stochastic (classical type)	Probabilistic nature of the investigated processes and phenomena.	The risk of incorrect calculation of the investment project dynamic capitalization and the discount rate.
Unknown events distribution at the large sample	Such situation arises at the assessment of damages. Assessment bases on the market value loss and loss of profits.	Indices are highly susceptible to market conditions, which depends on many factors. These factors cannot be exact calculated. As a consequence, there is a risk, that the damage distribution cannot be established.
Perspective	Possible manifestation of such factors as: • change the interest rate and credit policies; • strong fluctuations of the exchange rate; • inflation; • complexities of the technogenic processes.	Risk of the project cash flow strong deviation from the planned values.
Retrospective	The lack of information about the object behavior, due to low system efficiency of the collection, exchange and storage of information within the enterprise.	Risk of fluctuations of the investment projects efficiency indices.
Technical	Limitation of the methods and tools used in the analysis process. For example, imperfection forecasting methods, the	Risk of the project cash flow deviation from the planned values. Technical risks.

	lack of the necessary software at the enterprise and so on.	
Uncertainty of the nature states	Partial or complete ignorance of the environment conditions, and also likelihood of it changes.	Environmental risks.
Uncertainty of resistance	In the case of interaction between two or more parties, each party has incomplete and inaccurate information about the behavior reasons of the other side or does not have any information.	Economic risks associated with defaults, for example, failures to deliver equipment, materials and so on.
Uncertainty of goals	The variety of purposes, including the controversial and necessity to solve multicriterion problems as the result of it.	Risk of the investment project effectiveness reducing as a result of failing to achieve the main goal.
Uncertainty of terms	The lack of information about the terms, at which decision is assumed.	Risk of the company potential incorrect assessment.
Linguistic uncertainty	Verbal description of the studied process or phenomenon is not perceived from a mathematical point of view.	Risk of the cash flow volatility increasing due to incorrect interpretation of the existing information in the non formalizable form.

To estimation of the uncertainty effect the different ways can be used. The most popular of these is the sensitivity analysis and simulation modeling.

Sensitivity analysis involves the assessment of the final solution reaction to changes in individual characteristics and risk factors. Sensitivity analysis also can be useful for uncertainty reduction: identifying model inputs that cause significant uncertainty in the output and should therefore be the focus of attention if the robustness is to be increased (perhaps by further research). As the risk factors is selected those factors, which characterized a maximum uncertainty in the estimates of their values. For example, in the case of adverse events probability uncertainties in some period of time can be three options: the maximum probability, the minimum probability and the most reasonable probability.

Risk and the most effective strategy, designed to reduce this risk is estimated for each of the options. If the difference between the estimates and the corresponding strategies is negligible, it can be assumed, that the uncertainty of the adverse events probability will have no impact on the result. This approach can also be applied to the uncertainty of such characteristics as damage assessment and so on. This method is the most effective in the case of higher-order uncertainty, such as the «unknown distribution of events with a large sample».

Simulation modeling is also the effective way to assess the uncertainty impact on the resulting solution.

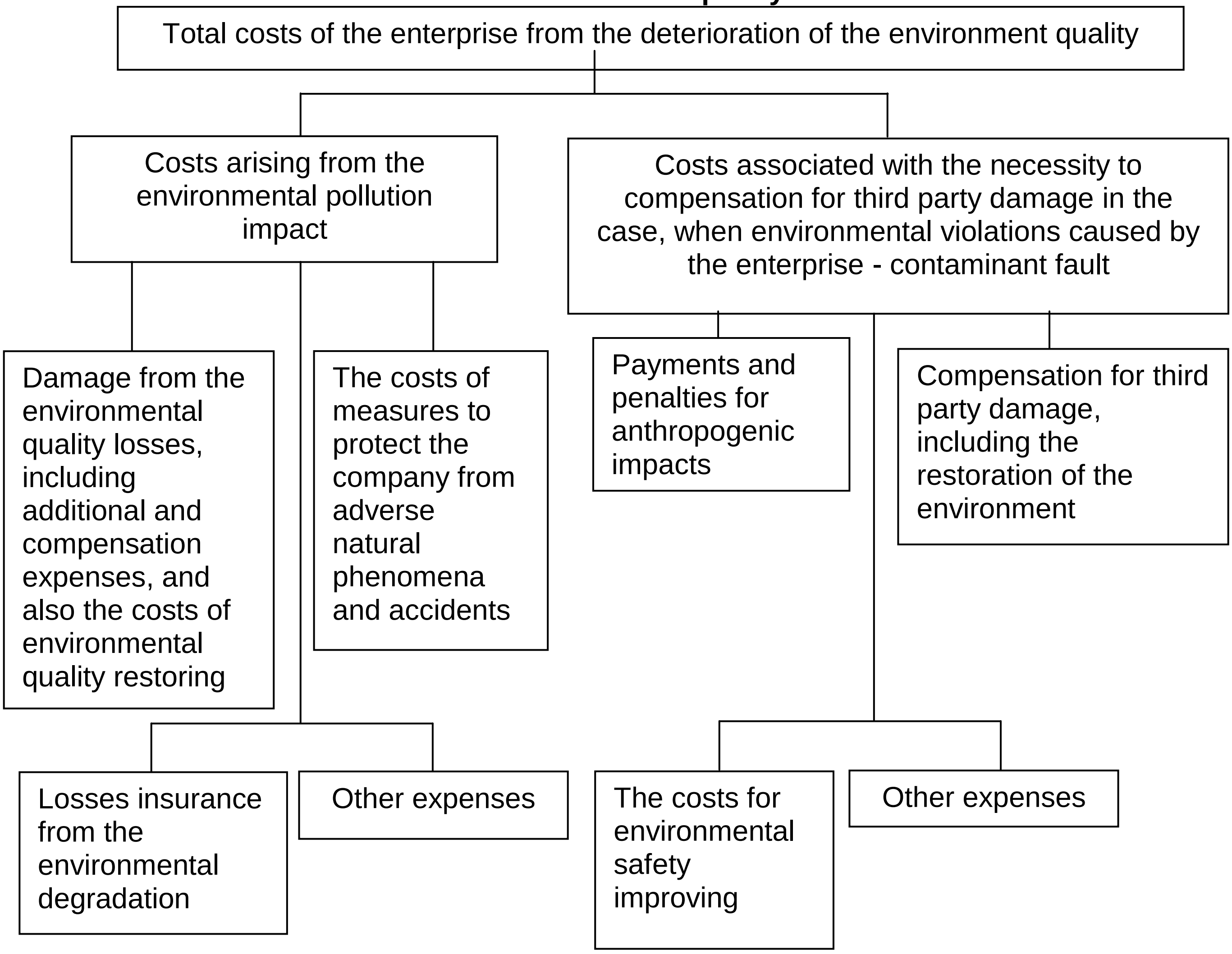
Monte Carlo methods are mainly used in three distinct problems: optimization, numerical integration and generation of samples from a probability distribution. Monte Carlo methods are especially useful for simulating systems with many coupled degrees of freedom. For example, using the Monte Carlo method can be formed the different variants of unknown parameters distributions and obtain optimal solutions for them.

The implementation of the Monte Carlo method provided in many decision support systems. The basis of simulation approach is the use of computer technology, particularly the analytical programs that allow simulating the unknown values, to build multidimensional tables, on which can explore and graphically display the results of changes in more than one factor.

3.2 Environmental Costs

Economic aspects of the risk analysis in environmental issues, associated primarily with the assessment of the damage which the object may incurring due to deterioration of the environment quality (Tikhomirov, Potravny & Tikhomirova, 2003). Total costs (see fig. 1) can be divided into the two components. The first component isa loss of the object caused by deterioration of the environment quality, the second is all the costs associated with this deterioration.

Figure 1: Structure of the enterprise total costs resulting deterioration of the environment quality

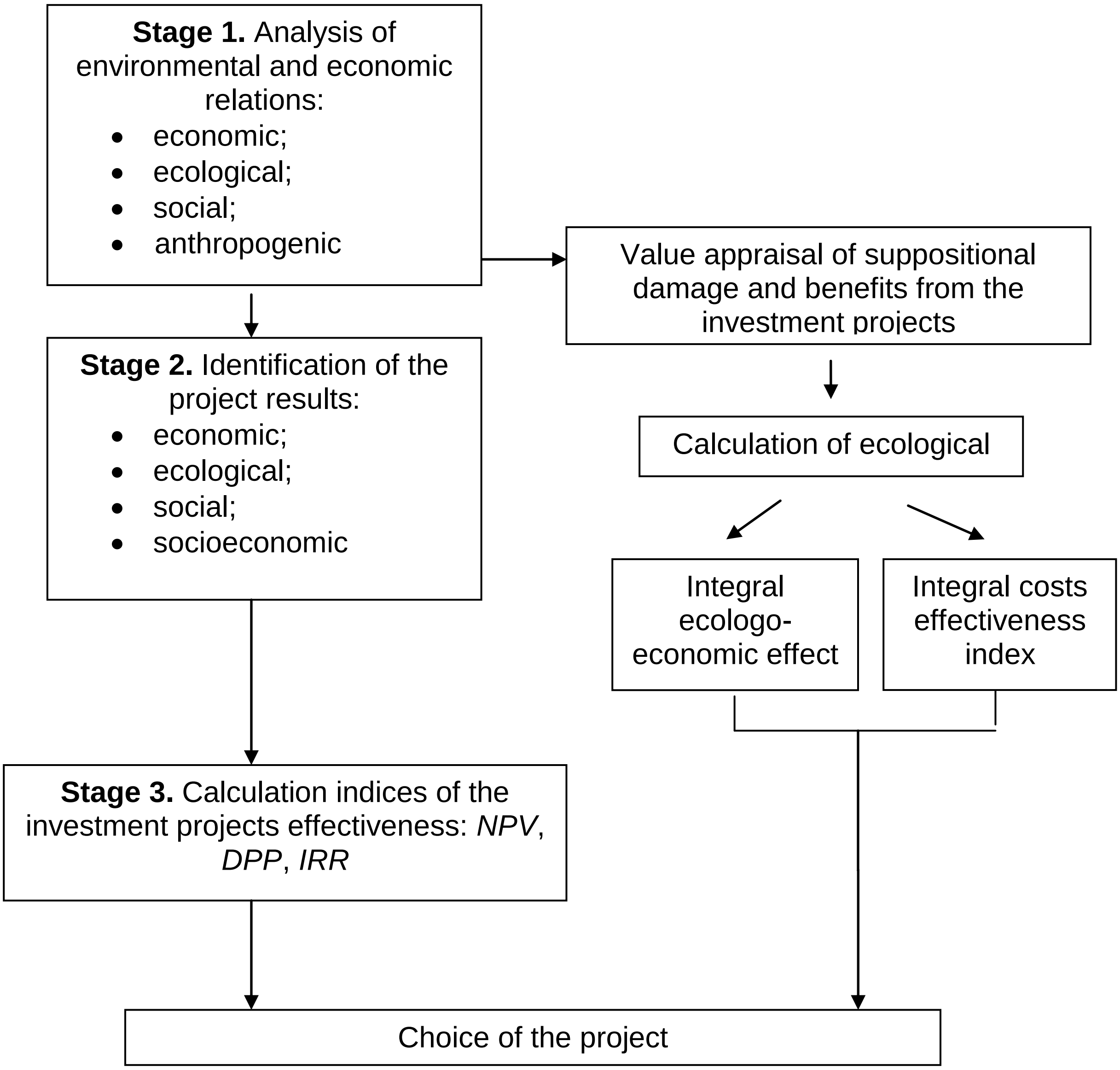


Based on the socioeconomic reasons, such as the desire to reduce the cost loading of producers and strengthen their position at the international markets, unfortunately, the legislation of some countries do not provide full losses compensation, suffered by companies fault.

3.3 Innovative Approach to Investment Projects Evaluation

At the fig. 2 algorithm of the investment projects environmental and economic evaluation is shown.

Figure 2: The algorithm of the investment projects environmental and economic evaluation



3.4 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 (Gluhov, Lisochkina & Nekrasov 1997):

- ✓ 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 (Nujina 2010). Ecological flow value is calculated as:

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

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:

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

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:

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

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:

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

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:

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

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:

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

where *E* is the discount rate. The project will be considered effective if E^{IEE} is a positive.

Integral costs effectiveness index:

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

The criterion of cost effectiveness is the ratio:

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

3.5 Indices of the Investment Projects Effectiveness

Third stage of the algorithm 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. 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 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:

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

The left-hand side of equation (10) is a 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

$$\mu_A(0) = sup_x\left(\mu_A(x)\right). \qquad (11)$$

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:

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

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 $\overline{\overline{IRR}}$:

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

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 $\overline{\overline{IRR}}$: $defuzz\left(\overline{\overline{IRR}}\right)$.

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 (Konysheva & Nazarov 2011):

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

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

$$\mathrm{fuzziness}(A)=\int_E\left|\mu_A(x)-\mu_{A_0}(x)\right|dx. \qquad (15)$$

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 - $fuzziness\left(\overline{\overline{IRR}}\right)$ should be minimal. Therefore, the second component of the function, requiring of minimization, can be represented by the following formula:

$$\mathrm{fuzziness}\left(\overline{\overline{IRR}}\right)=\int_R\left|\mu_{\overline{\overline{IRR}}}(x)-\mu_{\overline{\overline{IRR}}_0}(x)\right|dx. \qquad (16)$$

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

$$fuzziness\left(\overline{\overline{IRR}}\right)+defuzz\left(\overline{\overline{IRR}}\right)\to min. \qquad (17)$$

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:

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

  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. The Findings

The complex estimation of the project with using information in the fuzzy form at the investment projects analysis and the construction on the basis of a cash flow increases the accuracy of the project evaluation on 25% compared with traditional methods.

The costs of measures to protect the environment can be considered as an effective, because at the 2,1% value of GNP they prevent about 3-5% damage of the GNP.

The proposed methods of investment projects estimation has a number of new aspects, especially in the field of environmental factors accounting. Since the economic strategy of the Russian Federation focuses on social programs and programs of technical modernization, environmental factors must be taken into account in the economic policies. In this regard, the proposed scheme fundamentally different from traditional approaches to the development and evaluation of investment projects.

5. Summary and Conclusions

According to the method of environmental and 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 environmental and economic evaluation of the project is an important investment designing tool.

So, the proposed methodology is the basis for the further integration of environmental factors accounting in the investment analysis system of companies. 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.

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Appendix

Figure3: The scheme of an individual approach to ecologically clean manufacturing in Russia at the period from 2009 to 2013