NPV simulation as a way to reduce uncertainty in the project

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S u m m a r y : *The purpose of the study is* to develop an approach for the simulation of the net present value of the project in terms of uncertainty and incomplete information. To achieve this goal. *The methodological basis* of the study consists of the graphic modeling methods, comparative analysis, the method of analogy, scientific methods of analysis and synthesis, discounting method, method of computer simulation. *The main results of the study.* The lack of studies devoted to the profile of the cash flow effect for the project specification was shown. The concept of uncertainty as the decision maker's state in terms of information insufficiency was clarified. The coefficient of underdeterminess of the cash flow as the value that characterizes the knowledge of the decision maker in comparison with the actual flow profile in the future was introduced. For its calculation the model of displaying of the project cash flow profile in the operational phase in the form of five zones of the sectionally-broken line was proposed. By analyzing the results of the computer simulation it was proved that the value of the coefficient of underdeterminess has functional dependency with the shape of the cash flow of the profile and reflects its features. The procedure of the information preparation for the decision maker was developed. This procedure reduces the rate of the coefficient of underdeterminess of the cash flow.

K e y w o r d s : project, uncertainty, simulation, modeling, simulation modeling, underdeterminess coefficient, cash flow profile

INTRODUCTION

The last two decades of the civilization existence refer to the implementation (not the origin) of transition to the knowledge society. Many facts confirm this. Thus, in 2000 the Lisbon program [35] entered into force. This program identified key strategic areas of economic and social innovations in Europe in the beginning of the XXI century. The program says that Europe must revise the strategies for fuller manifestation of a new society that is focused on knowledge. The main goal, which identified future policy actions, became "the creation of special, dynamic and knowledge-oriented economy".

In 2005 UNESCO published the world report "Towards knowledge societies". It contains the following: "it is generally accepted that knowledge has become a subject of enormous economic, political and cultural interests as much so that can determine the qualitative state of society, the outlines of which are just beginning to emerge in front of us. Knowledge society, … , there are no any doubts concerning the importance of its concept, whereas the state of things concerning its intension is not so good" [37]. The last statement indicates that the uncertainty is increasing in society about many aspects of life.

However, the presentation of the modern society as a knowledge society is only one of the metrics of processes vision that are taking place in civilization. Other metrics (visions) also exist. For example, the study [32] indicates that the modern society is characterized by the following diverse indicative terms, such as post-industrial, network, creative, innovative, service, information, science intensive, knowledgeable, risk society and so on. But, as the study [15] states, “despite the interpretation differences, every definition contains unity of views, which is that the transformation of the modern world is inseparably linked with the key role of information flow, advanced technologies and theoretical knowledge”.

As we can see, from the point of view of one of the metrics the modern society appears as a risk society. Ulrich Beck has invented this term on the basis of the established fact that in the modern society "risk involves industrial, i.e. technical and economic decisions (feasibility), and utility evaluation. As opposed to “war losses” risk differs in its “normal birth” or, more precisely, in its “peaceful origin” n the world centers of rationality and prosperity under the cover of law and order” [3].

Therefore, “our society of ultimate risk has become the society without guarantees, it is not insured, and the paradox is that security decreases with the growth of dangers” [3]. And the essence of "risk society" can be defined through the logic of production of industrial society (the accumulation and distribution of wealth), which transforms into the logic of production of mass distribution of risks that are generated by scientific and technical systems [4]. Ulrich Beck believes that the development of civilization provides us with risk and it becomes the backbone principle of society that makes its essence. Unlike past eras’ hazards, risks are a direct result which is connected to threatening power of modernization and global instability and uncertainty generated by modernization. In the risk society the unknown and unexpected effects become dominant forces [4]. In the risk society avalanche-like socio-economic process (such as panic, agiotage) appear very often and they characterize society as unstable and crisis [7].

The overview report of the World Bank World Development 2014 “Risk and Opportunity: Managing Risk for Development” points, “The changes that are taking place in the world are accompanied by the rise of variety of new opportunities. However, both new and old risk factors arise.” [39]. But risks are only the way of how uncertainty comes out while uncertainty itself is an essential characteristic [11]. Uncertainty is the state of ambiguity of future events and impossibility to predict them and it is caused by informational incompleteness and incorrectness [17].

New opportunities open new horizons for the implementation of new innovations especially process innovations at the first place. Process innovation is the implementation of a new and dramatically improved production or delivery method. This includes significant changes in technology, production equipment and/or software [27]. To implement innovations in the terms of uncertainty and risk is impossible without the use of project management tools.

BACKGROUND

Project management is now seen as the process of making competent decisions regarding effective and efficient coordination of actions as an integrated system to produce a product with unique features of performance value, quality, time, cost and satisfaction of stakeholders [29]. This process takes place under conditions of uncertainty. When creating an innovative product uncertainty always increases due to the change of technological processes. According to many researchers uncertainty is primarily associated with insufficiency [13], incompleteness [10], unreliability [6], and deficiency [23, 31] of information. It is possible to receive information either by force of prediction or by simulation modeling of the future. Simulation modeling allows establishing the presence and the type of cause-and-effect relations, to identify their nature, to find the most rational parameter values of the simulated system, etc. Owing to this fact insufficiency, incompleteness, underdeterminess (rus. недоопределенность) and other non-factors reduce [24], as well as integrally they determine the essence and the extent of uncertainty. Nowadays the modeling of uncertainty and risks is satisfactory developed for technical systems [16]. At the same time it is considerably worse developed for socio-technical and social systems. The evidences from the study [38] confirm this. It shows, for example, that risk management takes one of the last places among the techniques and methods of management functions implementation for all types of projects (social, economic, organizational and technical). The study [18] cites data that confirm a sustainable growth of the number of publications which are devoted to "uncertainty". However, most of them do not apply modeling techniques to reduce uncertainty. The largest amount of studies in this direction is connected to the simulation modeling of investment processes [5, 14], investment strategies [22, 36], net cash flows [8], in the terms of uncertainty. The studies [19, 20] and other researches describe the results of simulation modeling of various factors on the NPV value which is net present value of a project. In particular, there were some impacts of project risks simulated through the changes of discount rates, various response events and others. However, the author is not aware of the studies that take into account the nature of cash flows of a project as an indicator of uncertainty of a project. This problem arises in practice when choosing one of several projects with approximately equal values of NPV, but with different types of cash flows. In addition, in the phase of doing feasibility studies the task of finding an indefinite cash flow with the desired NPV value can arise. Besides, doing feasibility studies may challenge the selection of uncertain cash flow with the desired NPV value. This task is relevant in the absence of reliable information about the volume and possible price characteristics of goods (services), which will be implemented during the operational phase of the project product.

PURPOSE AND RESEARCH PROBLEM STATEMENT

The purpose of this study is to develop an approach for simulation modeling of project activities in the terms of insufficiency and incomplete information about the characteristics of cash flows at the operational phase of the project product. The information received as the result of modeling should have some value for the decision maker of a project. Only in this case it will be a means of reducing of uncertainty. Thereby, the approach should take into account the peculiarities of decision maker's perception of instability and uncertainty of the environment in which the project product will be operated.

METHODS

The methodological basis of the study consists of the graphic modeling methods, comparative analysis, the method of analogy, scientific methods of analysis and synthesis, discounting method, method of computer simulation.

FINDINGS AND THEIR ANALYSIS

Let's define the terminology platform of the research more precisely. There is a need to do this for the following reasons. Firstly, the terminological system formalizes the object and the subject of the study. Notably, it is the basis of an idealized descriptive model of the subject field (phenomenon, process) which will be explored. Therefore, the terminological system always reflects a certain degree of abstraction in the description of the study area [9]. The subject of the study and research is the object's essential part which is allocated in terms in the form of distinguishers that are fixed in verbal definitions. Besides verbal definitions allow to expose dishonest sources of information (messages) that contain meaninglessness of some proposals (sentences) [28].

Secondly, the fidelity of verbally formulated definitions will depend on the understanding of its constituent terms that are defined ostensive, i.e. using sensory perceptions. This determines the degree of ambiguity, and hence the uncertainty for the person who will use the terms and information about the results of modeling for making a decision. Therefore, for different people, the same information will reduce uncertainty in varying degrees.

Based on analysis of more than 30 definitions (idealizations) of the term "uncertainty", we propose the following version of its definition. Uncertainty is a state of a person that is determined by his/her knowledge system concerning the impossibility/possibility of decision making as to further activity in a particular situation on the assumption of insufficiency/sufficiency, inaccuracy/accuracy, incorrectness/correctness and other information about events that are associated with future activity and their impact and effects on the expected values (planned output).

Any decision making involves evaluation (of the situation, parameters, etc.). Therefore, a decision maker always operates qualitative or quantitative data, which are expressed in numeric characters, even if it is fuzzy input. Based on this definition of uncertainty it is possible to say that a decision maker uses underdetermined data values (non-values). Underdeterminess means that some kind of data (member object/instance variable) is inherently more accurate in comparison with what currently available information about the object allows to set [24]. Underdeterminess reflects not only data properties but also knowledge properties that are defined as a partial knowledge of the content x and that is limited by the information that *x* belongs to some specific set *X* [25]. Therefore, in the future in order to distinguish the concept of the term "uncertainty" as a condition of a value taker's state from the characteristic of this state we will use the term "underdeterminess".

Based on the proposed definition, the main task of simulation modeling is providing a decision maker as with specific, unambiguous information about project performances, as with information of how it was obtained and on what assumptions (idealizations) of a particular situation it was based. Such representation has some advantages.

In the first place, the decision maker of a project receives information data and then, after having realized it, chooses an alternate solution independently and in accordance to his/her priorities.

In the second place, such type of informational presentation gives an opportunity to assess the degree of underdeterminess, the complexity of a project, and helps to refer a project to one of the four groups proposed in the study [21]. This by-turn helps to define a basic set of operational procedures that are "almost sufficient" to begin the execution of a specific project.

In the third place, in the implementation phase of the selected variant of the project persons who will do that will be able to take some underdeterminess off in assumption that underdeterminess always occurs and is associated with an alternative choice of the project. At the same time, these persons perceive decision making in their own way, as well as they will be able to implement an adopted decision in their way in real situation which will take place at the moment of decision's implementation but not in an idealized one. To do this, depending on the complexity and underdeterminess of the local situation they independently choose additional procedures that were not in the core set. In such situations socio-normative models of individual behavior occur [12].

Carrying out an investment analysis in the initialization phase the project parameter NPV is often used as a basic one [30]. To model this parameter it is necessary to fix a few characteristics that are included in the formula for calculating:

$$NPV = \sum_{i=1}^{n} \frac{C_i}{(1+r)^i} - IC_o \, , \qquad (1)$$

where: C_i - is the integral value of the cash flow in i th year of the operational phase of the project product,

IC_o - is the cost of creating the project product,

r - is the discount rate,

n - is the duration of the operational phase of the project product.

As we can see there are three parameters. They are the cash flow which is in the operational phase of the project product, the cost of creating the project product, and the third and the most important parameter is the discount rate. It should reflect the peculiarities of decision maker's perception of the complexity and underdeterminess degree as well as project complicacy not only in the initialization phase of a project but in the operational phase as well.

To simulate cash flow in the operational phase let's assign it in the form of a chain line (sectionally-broken line) which has five sections (or six characteristic points) (Fig. 1).

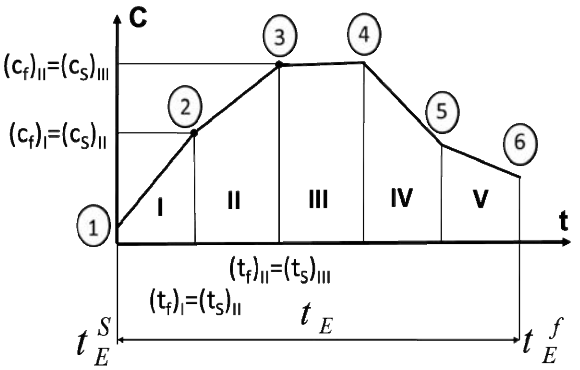


Fig.1. The cash flow representation in the operational phase of the project product

This is not a generally accepted way of cash flow representation. But it allows representing of any cash flow with an accuracy that is adequate for the initial phase (15-20% [34]) where the indicator NPV is calculated (Fig. 2).

In addition, it fully meets the recommendations of project risk management that are developed in the study [26]. It says, "Special attention should be paid on the conceptual risks and not to follow the technologies of detailed development in methodological researches spending limited resources on small problems and forgetting the fundamental strategic risks". The representation of cash flow in the form of a chain line allows conceptual reproducing of the zones of capacity expansion (product ramp-up), stabilization and recession.

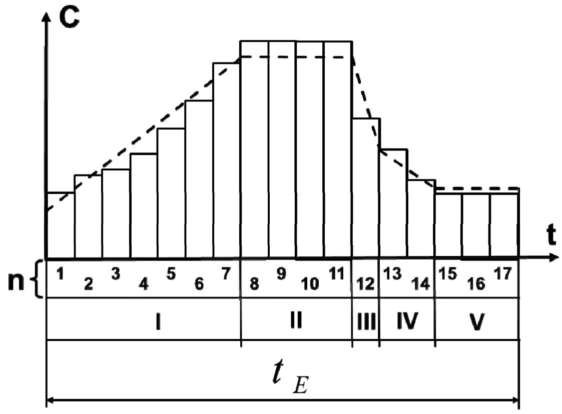


Fig. 2. The replacement of the traditional way of cash flow representation when the operational phase duration is 17 time periods into chain line with five zones (sections)

Every zone can be set as the following tuple $\{t_S, c_S, t_f, c_f\}_i$, where the index s means the beginning of a leg (section), f is its end, and i is the number of a leg of a chain line. Moreover, parameter values should be equal for the adjacent sections:

$$(t_S)_i = (t_f)_{i-1},\ (c_S)_i = (c_f)_{i-1},\ t_E = \sum_{i=I}^{V} t_i. \quad (2)$$

Such cash flow representation allows considering of it's changing within the period. For example, Fig. 2 shows that during the period II cash flow has not changed, and in the period III it has sharply declined. This reflects the business strategy which is laid when it is created on the basis of the project's product.

Due to this fact it is possible to simulate alternative strategies, thereby reducing the degree of uncertainty about the operational phase of the project product.

In regard to IC_o which is the cost in the initial phase of the project product, it is usually given as one indicator of a fuzzy number [2]. This assumes that in the operational phase the modeling results are also fuzzy represented.

In order to make the discount rate reflect decision maker's peculiarities of perception the degree of underdetermines and the complexity of the project as in the initialization phase of the project as in the operational phase the following approach is being proposed. Let's consider two projects with idealized versions of cash flows. The first project has the largest annual cash flow in the initial period of the operation phase and then project's cash flow is uniformly decreasing till the phase ends (Fig. 3 a). And the second project has the largest annual cash flow in the closing phase (Fig. 3 b). If the NPV for both of these projects will be the same, then obviously the first project should be chosen as far as the possibility of its full is much higher than for the second project. So we can say that the decision maker has lower underdeterminess relative to the first project than to the second one. However, in the real world such choice is practically not possible when the cash flows have compound forms.

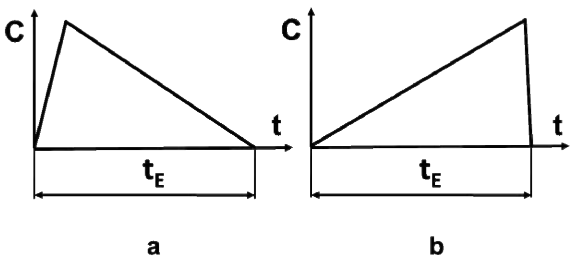


Fig. 3. Alternative form types of cash flows

Therefore, the following problem arises. How to take into account the different types of the cash flow of the project? The solution requires the decision makers to initially express their degree of underdetermines in regards to the project as to a holistic phenomenon in the form enlargement factor of the standard discount rate K_b. The more we have initial information about the project, options (scenarios) of its implementation, the possible events that can affect both positively and negatively on the value of the project the more awareness becomes and, therefore, the less the value of K_b coefficient should be. The value of this coefficient also affects the complexity of the project.

The second parameter is the K_f coefficient. The decision maker specifies it. It is associated with underdetermines compensation regarding the reliability of refund, which should arrive in the last period of operational phase of the project, compared to the degree of underdeterminess regarding to the initial period. This coefficient should affect the discount rate and vary from 0 to 1. It is logical to assume that if the projected income's return year lies after the start of the operational phase of the project then the discount rate should be higher. Then, on this basis, for the cash flow of each period of the phase we must consider its discount rate. At the present time we know the studies where the discount rate is taken on different values in different periods of the operational phase of the project (for example, [1]). However, such studies do not consider its representation with an allowance of a decision maker.

Taking a linear subjection of variation of K_f coefficient for the current year of operation in the first approximation it can be calculated as:

$$\beta_i = \frac{i - t_E^S + 1}{t_E^f - t_E^S + 1} \cdot K_f , \qquad (3)$$

where: i – is the current year of the operational phase starting from the beginning of the project,

t_E^S, t_E^f – are the years of the beginning and the end of the operational phase starting from the beginning of the project.

On this basis the discount rate for the current year can be calculated by the formula:

$$r_i = (1 + \beta_i) \times K_b \times r_b . \qquad (4)$$

From the viewpoint of reducing of the underdeterminess of the project it is reasonable to enter a coefficient of reduction for underdeterminess of the cash flow's type. Let's represent the cash flows of the project in relative units. To do this, we divide each average value of C_i on the sum of all flows of operational phase $\sum C_i$. We denote the obtained values through α_i.

In this case $\sum \alpha_i = 1$. I.e. we obtain the normalized cash flow for a specific project. Thus we can calculate the net present value for a project which has the amount of the discounted cash flow equal 1:

$$NPV = \sum_{i=t_E^S}^{t_E^f} \frac{\alpha_i}{(1+(1+\beta_i)\times K_b \times r_b)^i} . \quad (5)$$

This value is not normalized, i.e. does not vary from 0 to 1. To disclose its content we will do normalization. Then we will calculate npv for two projects. The first project has not discounted unit flow in the first year of the operational phase, and the second project has it the last year:

$$npv_S = \frac{1}{(1+K_b \times r_b)^{t_E^S}} , \quad (6)$$

$$npv_f = \frac{1}{(1+(1+K_f)\times K_b \times r_b)^{t_E^f}} . \quad (7)$$

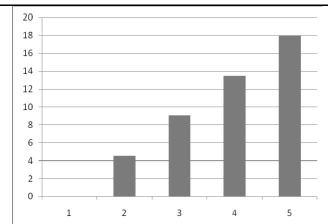
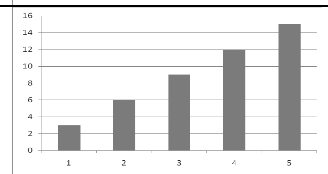
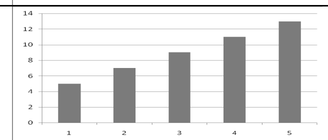
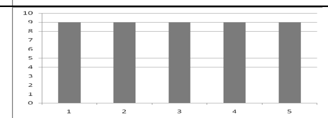
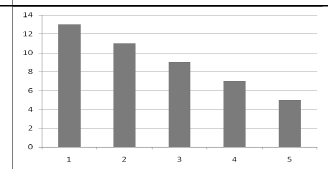
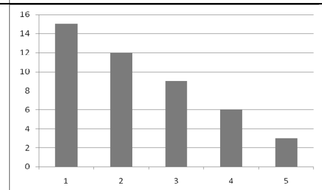
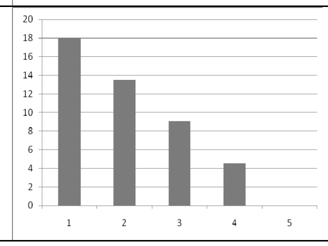
Thus for any kind of cash flow in the implementation phase the underdeterminess's reduction coefficient of the cash flow's type can be calculated as:

$$K_{dv} = \frac{npv_S - nnv}{npv_S - npv_f} . \quad (8)$$

Let's do the calculation for the K_{dv} coefficient's variation for different cash flow profiles. The simulation method of various forms of profiles is widely and successfully applied in the study of technical systems [33]. We will assume identical initial conditions for all profiles' options. Let r_b =0,2, I_o =15 monetary units, $\sum C_i$ =45 monetary units, K_b = 0,5, t_E^S , is the second year of the project, t_E^f is the sixth year of the project. Table 1 shows various cash flow profiles, NPV and K_{dv} values.

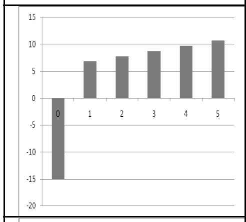
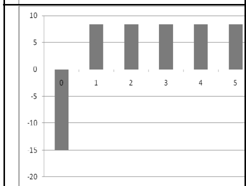
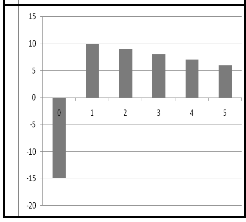
The correlation coefficient calculations between NPV and K_{dv} show that it equals -1. This indicates that the proposed coefficient has a functional relation to the form of the cash flow profile which linearly varies from «min - max» kind to «max - min» kind. For that reason it will properly reflect its peculiarities for any form of cash flow profile. To confirm this assertion we carried out additional calculations. We considered three projects that had equal values $\sum C_i$ = 15 monetary units and NPV =10 monetary units, while the forms of cash flow profiles are different (Table 2).

Table 1. Calculating results for project performance

№	Cash flow profiles	NPV	K_{dv}
1		7,1	0,8
2		8,7	0,71
3		9,8	0,66
4		11,9	0,55
5		14,1	0,44
6		15,1	0,39
7		16,8	0,31

As one can see even with a relatively small flow increasing/decreasing by 8-10% during the five-year term of the project operation, the coefficient varies by 20-25%.

Table 2. The influence of the form of the cash flow profile on the value of the reduction coefficient of the underdeterminess of the cash flow K_{dv} type

Cash flow profiles	The base discount rate K_b increasing coefficient				
	0	0,25	0,5	0,75	1
	0,6	0,6	0,61	0,61	0,62
	0,55	0,55	0,55	0,56	0,57
	0,48	0,48	0,49	0,5	0,51

In addition, all other things being equal, K_b increasing makes K_{dv} increasing and makes its difference to decrease for different flow profiles.

The obtained simulation results allow us to recommend the following procedure as to information preparation in the initialization phase of the project for the decision maker concerning the further project implementation.

1. Preliminary cost information as for project product creation (I_o), base discount rate for this class and complexity of the project (r_b), possible operational term of the project product (t_E^S), intended type (profile) and the value of the cash flow in the operational phase (C_i).

2. To calculate the coefficient NPV the traditional method.

3. To presentat the cash flow profile as a sectionally-broken line with the anticipated operating conditions of the project product which determine sectionally-broken line’s type.

4. To make the decision maker acquainted with the prepared information. To get his/her opinion in regards to the discount rate increasing (K_b) and the heterogeneity compensation coefficient relating to the reliability and the refunds which should come in the last period of the operational phase (K_f).

5. The simulation of at least six cash flow’s forms that have identical sums of undiscounted flow $\sum C_i$ and that is equal the one that was used in the implementation of paragraph 3. These forms are the following:

- when $\sum C_i$ returns in the first year of project product operation,
- when $\sum C_i$ returns in the last year of project product operation,
- linearly increasing flow for which $NPV_{\min-\max} = NPV$,
- linearly homogeneous flow for which $NPV_{\min=\max} = NPV$,
- linearly decreasing flow for which $NPV_{\max-\min} = NPV$,
- linearly- increasing-decreasing flow for which $NPV_{\min-\max-\min} = NPV$.

6. To calculate the value of the heterogeneity reduction coefficient K_{dv} for all forms of the cash flow including the initial one.

7. The final representation of the information in the form of a table for the decision maker. This table must contain the type of flow forms and the value NPV and K_{dv} of each of them.

The implementation of the proposed procedure will reduce the underdeterminess of the decision maker concerning the project owing to the representation of results obtained during the simulation.

CONCLUSIONS

1. Based on the analysis of publications in the field of uncertainty and risk management it was shown that there is a lack of studies that would have been devoted to the effect of cash flow forms variation as one of the

characteristics that defines the uncertainty of the project.

2. It has become possible to identify the main reasons why this study is relevant after we have considered the need to clarify the research terminology base associated with uncertainty. These reasons are the need to describe an idealized model of the field of study through the separation of distinctive features in terms, subjective interpretation of the terms that are defined ostensive. This study proposes to understand the uncertainty as a decision maker's condition to make solutions in regards to further activity in a particular situation with the lack of information.

3. To characterize the heterogeneity it was proposed to apply the coefficient of underdeterminess which means the fact that the properties of the data and knowledge are inherently more accurate comparing to what currently available information allows us to discover.

4. Based on the nature of the proposed uncertainty definition the main task of the simulation in the project was formulated.

5. For the purpose to reduce the uncertainty in the project we propose the model of how to represent operational phase's cash flow in the form of a sectionally-broken line. It has made possible to introduce the notion of uncertainty reduction coefficient about the type of cash flow and develop an approach to its definition.

6. Based on the simulation results of various forms of cash flow it was proved that the proposed coefficient reflects its peculiarities due to the nature of the functional dependence with the cash flow.

7. On the basis of new scientific results we have developed the procedure of how to prepare the information for the decision-maker in the initialization phase of the project.

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МОДЕЛИРОВАНИЕ NPV КАК СПОСОБ СНИЖЕНИЯ НЕОПРЕДЕЛЕННОСТИ О ПРОЕКТЕ

Денис Рач

Резюме. Изложен подход к моделированию показателя чистой приведенной стоимости проекта в условиях неопределенности. Уточнено понятие неопределенности как состояния лица, которое принимает решение в условиях недостаточности информации. Введено понятие коэффициента недоопределенности потока. Для его расчета предложена модель отображения профиля денежного потока по проекту на фазе эксплуатации в виде пяти зонной кусочно-ломаной прямой. Разработана процедура подготовки информации для лица принимающего решение которая снижает коэффициент недоопределенности потока.

Ключевые слова. проект, неопределенность, моделирование, коэффициент недоопределенности, профиль денежного потока.