Risk assessment of innovative projects: development of forecasting models

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Abstract.

The purpose of this article is development a systematic dynamic complex model of generation and risk assessment of innovative project, on the bases of which a scenario modeling of many risks influence arising at certain stages of project implementation in the target area.

For article purpose realization, the paper proposes a complex toolkit for modeling the innovative projects risks in the direction of their impact on performance indicators in scenarios, which involves the implementation of the following stages of modeling: Stage 1. Collection and processing of project data; Stage 2. Evaluation of innovation project efficiency indicators; Stage 3. Formation and assessment of many risks of innovation project by components, nature and impact strength; Stage 4. Modeling of innovative project development scenarios.

The implemented set of models makes possible to compare all components of efficiency and riskiness, which determine the integrated aggregate level of project risk by components of life cycle risks, target project risks and scenarios depending on environmental factors and managers propensity to take risks, and solves the problem of positioning the real indicators state of innovation project efficiency in a comparative dynamic context based on three-level assessment, due to structural elements of risks and identification of possible and promising deadlines and time horizons by stages of the project life cycle, critical paths and reserves which allow us to achieve the main goal of improving the innovative projects implementation efficiency.

Keywords: innovative project, life cycle, risks, simulation model, business entities, challenges, scenario modeling, efficiency criterion.

I Introduction

Today realities show that modern world faces a large number of global challenges such as geopolitical, social, economic, biological, demographic, climatic, technological, informational, cultural, which are described by Tatar (2020). Global challenges radically change the socio-economic relations and interaction between states and business entities within states, require concentration and pooling of opportunities at all levels of government, determine the need to adjust the national strategy of socio-economic development and its innovative reorientation, encourage to fundamentally new approaches formation for business entities innovation activities management.

In the context of global challenges, the economic entities innovative activity is characterized by an increased risk level. The research of Ukrainian industrial enterprises innovative activity state shows that its level remains quite low. The share of industrial enterprises that have implemented innovations is about 11%. According to the Innovation Development Index presented by Bloomberg in 2018, Ukraine ranks 53rd among the 60 surveyed countries. The results of research by Ukraine State Statistics Service show that one of the main reasons that constrain the business entities innovation activity is the imperfection of institutions, especially the political, regulatory and business environment; high risks in the innovative projects implementation. In this regard, the project risks analysis, assessment and management is relevant because it will give an opportunity to really assess the prospects, in terms of selected project risk.

The innovative project risk is the possibility that the company will incur losses or in the form of additional costs in excess of the forecast; or due to exceeding the planned time of implementation of the innovation project stages; or due to loss of time due to the risk associated with the innovation commercialization in the market; or will receive income below those expected. These types of resources loss lead to a possible loss of profit under innovative project implementation in comparison with the forecasted variant. To ensure the objectivity of the analysis of enterprise innovation activities effectiveness it is necessary to quantify the innovative project risks value.

Problems of innovative projects research, their development in the conditions of risks are revealed in papers of such scientists as A. A. Abdalah, T. Barton, V.V. Bugas, I.V. Stepanova, A.V. Skrypka, W. Schenkeri and P. Walker, G.I. Karlova, V.O. Vasylenko, N.N. Lepa, R.N. Lepa, A.V. Grinyov, V.M. Grinyova, S.S. Sviridova and N.M. Gazheva, O.M. Zborovska, O.O. Okhrimenko and N. E. Skorobogatova and others.

The necessity and relevance of innovative projects research in condition of risks and today's global challenges, combined with the processes of integration, simultaneous neo-industrialization and deindustrialization are confirmed by the papers of foreign authors Barton, Schenkeri and Walker (2003) which emphasize the beginning of the process of forming the latest stage of society development – "risk society" – and claim that humanity has already entered this new phase / stage of development. This is due to the fact that in modern conditions most of the threats and risks caused by them are no longer local in nature, but become global. The main problem of future economic growth will be not so much the growing need for funds to finance new investments, but the need to reserve capital to meet those needs that will be caused by risks.

Researchers Lityuga and Revutska (2012) in the paper "Risks of innovation activity and modern outsourcing models of its implementation" to the innovation process risks types include: 1) the risk of wrong choice of innovation project; 2) the risk of not providing the innovative project with a sufficient funding level; 3) marketing risks; 4) risks of non-fulfillment of economic agreements (contracts); 5) the risk of increased competition; 6) the risk of staffing insufficient; 7) risks associated with securing property rights to the innovative project.

Grigorieva (2008) in her paper "Problems of risks that arise during the implementation of innovative projects and methods of their quantitative measurement" analyzes the risk concept, considers options for innovative risks and provides different classifications of risks that may face the company during implementation of innovative projects.

Risk assessment of investment in innovation are considered in Kushnir and Vernydub (2018) papers. The paper of Bugas, Stepanova and Skrypka (2019) is devoted to the international experience of risk management of enterprise innovative activity. Iarmosh, Prokhorova, Shcherbyna, Kashaba and Slastianykova (2021) investigate innovativeness of the creative economy as a component of the Ukrainian and the world sustainable development strategy.

For successfully building of innovative projects mathematical model, it is necessary to have a well-established theoretical basis and significant empirical experience. Such model should be representative; take into account the key factors influence; take into account the impact of major constraints; be flexible and predictable. In essence, these requirements are common in the construction of any mathematical model. Such requirements are met by traditional stationary statistical models. Innovative behavior in such models is interpreted as a one-time action performed by the innovator (business entity). The consequences of such action should be Pareto-optimal and lead to equilibrium in the innovation market. However, considering the objective complexity of innovation processes in general and innovation projects in particular, another specific requirement must be put forward for modeling such processes - taking into account a high degree of uncertainty and risk. However, most methods and models do not take into account the risks impact.

Methods of innovative projects risk assessment include the method of project sensitivity analysis, the method of scenarios and methods of simulation. These tools are used in the paper to assess the risk and effectiveness of innovative projects. Among the methods of risk management, scientists identify the following methods: risk allocation; diversification; reduction of uncertainty; limitation; hedging; insurance.

When evaluating the innovative projects effectiveness, the resulting indicator is usually one of the efficiency criteria: net present value (NPV), internal rate of return (IRR), profitability index (PI) and payback period.

The most common of these are the expected net present value method, sensitivity analysis and the risk-adjusted discount rate method. The general advantage of these methods is their relative simplicity and clarity. Therefore, these methods are quite common in practice. But there is a common disadvantage for all these methods – they do not directly measure the risk. There is another difficulty in their application – due to the uniqueness of each innovation, there are no commonly used methods of objective assessment of the innovative project effectiveness. So the problem of objective assessment of the innovative project effectiveness and risks level remains relevant. Based on the chara?teristics of the most important innovation project features, it is necessary to assess its riskiness and innovative attractiveness. The usage of traditional methods of investment projects efficiency evaluation does not provide a sufficiently sound and reliable answer, methods of taking into account the risk of innovative projects have significant shortcomings and need to be improved. Economic and mathematical methods that can be used to select effective innovation projects include the use of expert assessments, simulation, scenario method, fuzzy set apparatus, methods for solving multicriteria problems and others.

The analysis of methods and models and their shortcomings which are used for innovative projects and risks modeling is carried out (Tab. 1).

Table 1. Analysis of methods which are used for innovative projects and risks modeling

Local tasks in innovation and risks research	Existing methods and models for solving the problem	Disadvantages of the methods
Innovative projects purposes, tasks deter-?ination	matrix methods of strategy formation, methods of analogies, expert methods; active search methods (surveys, exhibitions, fairs, publications); brainstorming, Delphi method, passive search methods (patent analysis, marketing research, proposals of consumers, developers and inventors); SWOT-analysis, system approach	usage of individual methods is ineffective, it is desirable to use combinations of different methods to obtain more accurate result
Assessment of innovation potential and results of enterprise innovation activity	methods of multidimensional statistical analysis (cluster analysis, factor analysis, taxonomy methods, etc.), expert methods; integrated indicators; correlation-regression analysis and optimization methods	the usage of individual methods does not give a complete objective assessment of the potential and results, more desirable is combination of different methods; limited sets of indicators for evaluating the results of innovation activity
Evaluation of innovative projects effectiveness	standard methods for evaluating the effectiveness of investment projects; projects break-even analysis	impossible to assess sufficiently complete assessment of the potential risks associated with the implementation of innovations and the impact of many factors, information on which is unclear or absent.
	methods of sensitivity analysis of projects	takes into account the change of one factor influencing the project results at constant levels of other factors, which is not true
	analysis of project development scenarios	require a large number of operations for the selection and analytical processing of information for scenarios, a limited number of scenarios; a high proportion of subjectivity in the scenarios formation
	decision tree	technical complexity of the method for large tree sizes, high subjectivism in determining probability estimates
	simulation methods (Monte Carlo)	high sensitivity of the result to the laws of probability distribution of input variables; the accuracy of the results depends on the initial assumptions and taking into account the interaction of the input variables
Evaluation of the innovation effectiveness	statistical methods, methods of economic analysis, method of analogies, analysis of time series, methods of correlation and regression analysis, methods of expert evaluations	require a large number of observations to obtain a qualitative forecast, the inability to take into account the individual characteristics of the research objects development

Estimation of the effect of enterprises innovation activity	model of susceptibility of enterprises to innovation based on the method of analysis of hierarchies	the model is based on expert judgment, i.e. inaccurate and subjective
	model of diffusion of new products taking into account uncertainty	the process of increasing consumers of new products is modeled
	technology diffusion model	the process of replacing existing technology with more modern, new technology is modeled, but the spread of innovations between enterprises is ignored
Innovative projects management	methods for evaluating the innovative projects effectiveness, methods of regression analysis, expert methods, SWOT-analysis, simulation, methods of dynamic programming for the allocation of resources between innovative projects	the proposed management methods are reduced to the selection of effective innovation projects
	systems analysis methods to identify the elements of the control system and the interrelation between them	models are generally conceptual in nature

To ensure the objectivity of the analysis of enterprise innovation activities effectiveness it is necessary to quantify the innovative project risks value. There are many approaches to risk assessment of innovative projects. However, due to the uniqueness of each innovation, there are no commonly used methods of objective assessment of the innovative project effectiveness. That's why the problem of objective assessment of the innovative project effectiveness and risks level remains relevant.

So despite significant developments in this area, insufficiently researched, in our opinion, remain some aspects of the application of modern economic and mathematical modeling to assess the future risks of innovative projects, which is especially relevant in today's global challenges.

II Methodology and Data

The research is based on the confirmation of the following empirical hypotheses:

Hypothesis 1 – the research of enterprise innovative activity efficiency is defined by necessity of reliable quantitative estimation of innovative projects local and aggregate risks level, and also influence strength.

Hypothesis 2 – the presence of certain specific features of innovative projects, which are determined by the high degree of uncertainty and risk associated with the project life cycle phases and its target orientation.

Hypothesis 3 – each phase (stage) of the innovative project life cycle has its own characteristics that take into account different types of risks, which differ in content and main causes.

Hypothesis 4 – each innovation project can be characterized by efficiency indicators in terms of costs, revenues and deadlines, which form a set of target risks of the innovation project (risk of overspending, risks of underfunding, risks of overspending time on project stages realization).

Investigating the innovation processes effectiveness and considering the planning, development, implementation, and management of innovative projects, first of all, the condition of system management of dynamic object under the influence of external and internal factors is necessary. In view of this, the article purpose is development a systematic dynamic complex model of generation and assessment of innovative project risks on the bases of which a scenario modeling of the impact of many risks arising at certain stages of project implementation in the target area.

For achievement the purpose, the paper proposes a complex toolkit for modeling the innovative projects risks in the direction of their impact on performance indicators for scenarios, which involves the implementation of the following stages of modeling:

Stage 1. Collection and processing of initial project data.

Stage 2. Evaluation of the innovation project efficiency indicators.

Stage 3. Formation and assessment of many innovation project risks by components, nature and strength of impact.

Stage 4. Modeling of scenarios of innovative project development.

The methods of assessment the project investment attractiveness were used for complex algorithmic model implementation, at the same time the innovative project indicators calculation was carried out in the dynamics of 7 years, as well as scenario simulation with multicriteria selection and implementation of alternatives using full-featured software Vensim PLE, which occupies an important place among various forecasting methods of management decisions results as a basis for forecasting and analysis of high complexity systems.

The choice of simulation methodology for research of innovation projects risks and construction of forecast models is defined by the following advantages that are realized in paper:

– simulation modeling is a series of numerical experiments designed to obtain empirical estimates of the degree of influence of various factors (initial values) on some dependent results (indicators);

– the ability to establish interrelations between the initial and output indicators in the form of a mathematical equation or inequality;

– setting the laws of probability distribution for the key model parameters;

– conducting computer simulations of the values of key model parameters;

– calculation of the main characteristics of the distributions of initial and output indicators;

– wide possibilities of use, especially in the conditions of uncertainty and risk;

– convenience in combination with other economic and statistical methods.

The scenario method makes possible to combine the research of the resulting indicator sensitivity with the analysis of probabilistic estimates of its deviations. In the general case, the procedure for using this method in the process of investment risk analysis includes the following implementation:

1. Identification of several options for changes in key initial indicators (eg, pessimistic, most probable and optimistic).

2. Each variant of change a corresponding probabilistic estimate is assigned.

3. For each option the probable value of the criterion is calculated as well as estimate of its deviations from the average value.

4. The analysis of probability distributions of the received results is carried out.

5. The method makes possible to obtain a sufficiently clear picture for different options for project implementation, as well as provides information about the

sensitivity and possible deviations.

6. The usage of software can significantly increase the efficiency of the analysis by virtually unlimited increase in the number of scenarios and the additional variables introduction.

The research information base for the practical implementation of innovative project complex algorithmic model is the initial data of the industrial enterprise on the example of the project of new equipment creation for plastic processing, i.e. advanced model of thermoplastic machine, and new production organization – the department for the production of plastic products by injection molding on the basis of new automatic thermoplastic machines.

III Results and analysis

The main difference between an innovative project (IP) and an investment project is the high degree of uncertainty and risk associated with the phases of the project life cycle. An innovative project as an object of evaluation has the following main features: sign of change; sign of a limited ultimate goal; sign of limited duration; sign of limited budget; sign of limited necessary resources; sign of novelty for the enterprise implementing the project and for the market of the expected demand for the product (service) created in the project; sign of legal and organizational support; sign of differentiation from other enterprise projects.

Each phase (stage) of the innovative project life cycle has its own characteristics that take into account the types of risks (Tab. 2). The main conditions that negatively affect the project effectiveness are:

– shift of the planned terms of the end of this or that phase (12 stages);

– increase in planned costs associated with overspending of innovation funds (12 stages);

– reduction of planned revenues associated with additional risks that restrain the innovation commercialization in the market (only in the last 4 stages).

Table 2. The results of classification of the main causes of the innovative project life cycle risks

Stage contents	Causes of risks at the innovative project life cycle stages
1. Marketing and research of market needs (identification of ideas from consumers)	Probability of negative results of marketing and research works; the probability of erroneous discovery of a new idea or technology; the probability of occurrence of new problems during new ideas formation that can not be solved at the current level of science and technology; risk of erroneous segmentation of the innovation market; the risk of erroneous choice of the target market segment of the strategy; the risk of erroneous of innovation goals formation
2. Generation of ideas from other sources	Other sources of ideas for creating new products do not meet the needs of consumers
3. Selection of business ideas	Risk of erroneous selection of ideas and non-selection of business ideas; risk with the probability of new product success: technical completion of development, launch into commercial production subject to technical completion, economic success subject to launch into commercial production
4. Development of the product concept and its verification	Inefficiently developed product concept; lack of the principle of design by order of consumers; the risk of erroneous development of the initial positioning of the product and brand; ineffective testing of the concept on the relevant group of target consumers in order to find out their reaction

5. Business analysis (analysis of production and sales opportunities)	The risk of erroneous description of the volume of the structure of the target market and consumers on it, the proposed product positioning, as well as market share and the planned enterprise share; incorrect information about the planned goods price, ab distribution out the principles; the risk of erroneous total sales forecasting; risk of erroneous costs and profits forecasting
6. Product development	Ineffective transition of the idea into a real product (incorrectly developed R&D strategy); the risk of not finding unique resources due to the technical features of the innovation project; risk of interaction with partners (contractors); the cost of product development was higher than estimated
7. Tests in market conditions (trial marketing)	Ineffective testing of a new product in market trials; incorrect reaction of dealers to the appearance of a new product, its use and sale; erroneously determined market size and overall sales forecast
8. Preparation and production of goods	It is inefficient to start design, technological and organizational preparation of production for the purpose of goods introduction in the market; risks associated with securing property rights under the project; the probability of occurrence of incidental problems when using innovations that cannot be solved at the current level of science and technology
9. Implementation	Ineffective methods of informing potential consumers about a new, not yet known product, persuading them to try this product and ensure sales through retailers; the new product was poorly positioned, its advertising campaign was ineffective or the price was set too high; the risk of erroneous development of pricing and promotion strategy; the risk of unsuccessful organization of the sales network and the system of goods promotion to the consumer; the product has design defects; social, environmental and state restrictions; global risks and challenges
10. Growth	The idea itself was good, but the market size was overestimated; the corre-?ponding shock of competitors was stronger than expected; ineffectively developed strategy of differentiation
11. Maturity	Reduction of the product life cycle; the risk is associated with failure to achieve the goal of marketing "profit maximization and market share protection"; ineffi-ciently developed strategy for diversification of brands and models
12. Decline	The risk is associated with failure to achieve the goal of marketing "reducing costs and maintaining sales"

To ensure the objectivity of the analysis of enterprise innovation activities effectiveness in terms of risk, it is necessary to use adequate tools of methods and models for assessing and forecasting the whole set of innovation project risks.

Let's consider the offered model of an estimation of aggregate risks of the innovative project in more detail on the basic stages and steps which are realized in paper.

Stage 1. Collection and processing of initial project data. This stage involves the formation of a database of statistical factors, result indicators and a complete list of risks to build models of risk management and their impact on the resulting variables.

In paper one of the most important assessments of the effectiveness of the i - th innovative project is its revenue e_i^t. Revenue from the innovative project implementation is forecasted by the company before deciding on its implementation, so it is very important that such forecast was as accurate as possible.

Based on the project business plan, each innovative project can be characterized by cost indicators (c_t^i), where $\overline{1,T}$ is the stage of the innovative project life cycle, and revenue indicators (e_t^i), cash flows during the project start from the stage of innovation implementation, i.e. $t = \overline{9,T}$, where $T = 12$ according to the innovative project life cycle stages classification.

It should be noted that the initial data for assessing the innovative projects effectiveness are the forecast values of their cash flows:

– the flow of discounted costs for the project $dc_t^i(c_t^i, t, r)$

– the flow of discounted revenue of the project $de_t^i(e_t^i, t, r)$, where $r-$ discount rate.

For building a complex model and its components the following software variables that characterize the production and business processes are used: Cost risk; Income risk; Final performance of thermoplastic automatic machine (TAM); Average price; Number of manufactured products; Operating costs; Running costs; Sales volume; Equipment costs; Income tax rate; Income tax; Taxable profit; Investments; Net profit; Net cash flow; Service life; The number of operating equipment; One-off costs; Unit value; Book value; Depreciation of production equipment; Depreciation of production building; Quantity of installed equipment; Quantity of operating equipment; NA equipment per year; Wear; Wear of press forms; Accounts payable; Unit debt; Redevelopment costs; Establishment and maintenance costs; Quantity of equipment units; Profitability Index; Average discount income; Payback period; NPV; Discount costs; Discount income; Discount rate; Amount of discount income; Amount of discount costs.

Stage 2. The innovative project efficiency indicators assessment. The next step in assessing the innovative project effectiveness is such indicators calculation as:

– net present value of the project $NPV^i(de_t^i, dc_t^i)$;

– profitability index of the project $IP^i(de_t^i, dc_t^i)$;

payback period of the project $IT^i(de_t^i, dc_t^i, T)$.

Stage 3. Formation and assessment of many risks of an innovation project by components, nature and strength of impact.

In the process of selecting a priority innovation project and / or multidimensional ranking of alternatives by efficiency indicators in terms of risks under certain scenarios, it is important to prepare the project business plan and assess its overall integrated efficiency, as well as the distance from the moment of project implementation. The longer this period, the greater the degree of uncertainty of the impact on project indicators of both external and internal factors. Therefore, the project effectiveness assessment should be supplemented by an assessment of the risks that arise at each stage of the project life cycle (Table 2) and reflect the most significant risks of each of the life cycle stages ($R_1 - R_{12}$) and the overall innovative project risk assessment as a whole.

The next group of risks studied in the model is the target risks of the innovation project (Tab. 3), which can occur at any stage of the life cycle with certain features, namely:

– risks of overspending (vc_t^i);

– risks of underfunding (ve_t^i);

– risks of overspending time on project stages realization (vt_t^i).

For algorithm implementation, it is necessary to conduct an in-depth analysis of model variables to identify risk sources.

Table 3. Target risk analysis of the innovative project

Risk	Description
Risk of overspending (vc_t^i)	It can occur at any stage of the project life cycle. According to the studied project, the costs are carried out to a greater extent during the first year, because during this time all 8 first stages of the life cycle are completed. Therefore, we will assume that the impact of risk must be taken into account when modeling the cost of equipment unit and the cost of installation and adjustment of equipment operation. These types of costs are present to the 12th period of the life cycle, as it is planned to introduce the equipment gradually. It is also worth considering the risks of exceeding the current cost on 1 hryvnia of sold products, as the company can plan or forecast these costs, but exactly in the future it is impossible to know.
Risk of underfunding (ve_t^i)	It can occur due to a decrease in expected sales. So the impact of this risk type should be taken into account when calculating the variable "Sales volume". Risks of loss of income loss appear at the 9th stage of the life cycle, at the stage of implementation, and continue until the end of the period.
Risk of overspending time on project stages realization (vt_t^i)	It is advisable to study within the first eight stages of the life cycle, as the most important in this regard are the stages of preparation for the new products production, the timing of which may deviate significantly from the planned. Since under the terms of the project all 8 stages are implemented in the first year, so this excludes the possibility of a detailed study of time spending during this period.

Let us make a basic assumption about the method of formalizing the reflection of the risk impact at each stage of the life cyrcle on the amount of expected costs (investment, income, time) which is proportional to the risk amount of the respective stage. The rationale for the efficiency of the basic assumption is the innovation project uniqueness, which does not make possible to estimate in advance the law of distribution of the random value of risk in a single implementation scenario. The paper seems to be rational to obtain an optimistic, most probable and pessimistic limits of risk assessment.

The meaning of the innovative project risk indicators, which will be reflected in the simulation model is presented in the form of the following criteria and restrictions:

1) K_1 – a criterion that characterizes the total amount of overspending of investments in the implementation of all stages of the innovation project, which must be minimized under certain other conditions;

2) K_2 – criterion that characterizes the condition of minimizing the total amount of excess of the planned time of implementation of the first eight stages of the innovation project, related to the first two phases (innovation development and innovation implementation);

3) K_3 – criterion that takes into account the life cycle of innovation and reflects the time minimization due to the risk associated with the innovation commercialization in the market;

4) K_4 – criterion that characterizes the total amount of loss of projected income associated with market risk (total loss of income), which must be minimized under certain other conditions;

5) O_1 – restriction, which is a formalization of the requirement not to exceed the investments overspending at each stage of the planned amount of total investment, aimed at possible risks compensating;

6) O_2 - restriction, which is the implementation of the requirements for the allowable time limit of the innovative project on two components: the total duration of deviations of the first eight stages of the innovation project, starting with marketing and research and ending with the stage of preparation and development of innovation should be in acceptable

established time frames; the next component is the presence of the risk of extension of the terms of innovative project commercialization associated with the commercialization of innovations in the market;

7) O_3 **-** restriction that reflects the total loss of income due to the impact of market risks.

For the integrated aggregate risk assessment of the innovation project (V^i), it is proposed to use the apparatus of fuzzy sets. The calculation of the integrated assessment involves the implementation of the following steps:

Step 1. Classification of risks by determining the linguistic variable and fuzzy class-?fication of values of indicators of each type of risk. For the variable that characterizes the risk of overspending, we define the linguistic variable "Risk level vc_t^i " with the introduc - ion of five fuzzy subsets $\{R\}$ of the set of values vc_t^i:

R_1 – fuzzy subset – "very low risk",

R_2 – "low risk",

R_3 – "average",

R_4 – "high risk",

R_5 – "very high risk".

Similarly, we define fuzzy subsets for the risks of loss of income and overspending.

As an integrated innovative project risk assessment it is proposed to introduce the linguistic variable "Innovation Project Risk" with the values {Very low project risk, Low project risk, Medium project risk, High project risk, Very high project risk}.

Step 2. Construction of membership functions $\{\mu\}$ of fuzzy sets. On the bases of the analysis of the values of the linguistic variable "Risk of the innovation project", the membership functions $\{\mu\}$are determined , which correspond to fuzzy T-numbers $\{r\}$. Subsets $\{R\}$ are formed by constructing membership functions. Since the upper and lower values are set for each risk type, it will be advisable to use trapezoidal membership functions.

Step 3. Assess the significance of innovative projects partial risks for integrated risk assessment. Each type of risk at each stage of the life cycle is associated with an assessment p_t of the significance of this stage and an assessment p_v of the risk significance to assess the project overall risk.

Step 4. Construction of comlex innovative project risk assessment. The integrated risk indicator of innovative project is calculated by the formula:

$$V^i = \sum_{t,v} p_{vt} \sum_{j=1}^{5} \mu_{vj}\left(\alpha_j\right),$$

where α_j is the value of risk depending on the propensity of the decision maker; $p_{vt} = p_t \cdot p_v$ is assessment of the total risk of the project stage.

Stage 4. Modeling of innovative project development scenarios.

Thus, according to the results of the previous stages of evaluation, each scenario of innovation project development is characterized by the following set of evaluation criteria of innovative project:

$$Q^i = \{NPV^i, IP^i, IT^i, V^i\},\ i = \overline{1,n}.$$

Therefore, the problem of ranking scenarios from a set of alternatives becomes a problem of multi-criteria selection. This step should take into account the determination of the criteria weights, because they show the degree of risk appetite and individual preferences of managers, so they can be subjective. According to the obtained values of the generalizing criterion, the best scenario of the situation development is determined.

For the practical implementation of the proposed methods of innovation project risk management the simulation model of an appropriate innovative project is built on the example of new equipment creation for plastic processing, i.e. advanced model of thermoplastic machine, and new production organization – department for the production of plastic products by injection molding on the basis of new automatic thermoplastic machines. The implementation of the project will diversify the company's activities and increase company's sales. The initial data on the project are given in Tab. 4-5.

Table 4. Calculation of the innovative project indicators

№	Indicators name	Years						
		1	2	3	4	5	6	7
1	Number of operating equipment	20	56	95	95	95	75	39
2	Number of plastic products per year, thousands of pieces	2200	6160	10450	10450	10450	8250	4290
3	Sales volume, thousand euros	79,2	221,76	376,2	376,2	376,2	297	154,44
4	Current expenses, thousand euros	49,1	137,49	195,62	195,62	195,62	163,35	84,94
5	Depreciation of production equipment, thousand euros	9	25,2	42,75	42,75	72,75	33,75	17,55
6	Wear of special purpose devices, thousand euros	1,8	5,04	8,55	8,55	8,55	6,75	3,51
7	Depreciation of a production building, thousand euros	0,8	0,8	0,8	0,8	0,8	0,8	0,8
8	Taxable profit, thousand euros	18,5	53,23	128,48	128,48	128,48	92,35	47,64
9	Net profit, thousand euros	12,95	37,26	89,94	89,94	89,94	64,65	33,34
10	Net cash flow, thousand euros	24,55	68,3	142,04	142,04	142,04	105,95	55,2

In paper Abdalah A.A. (2004) the main causes of the innovative project risks in accordance with the stages of the life cycle are identified, and expert assessments of the lower and upper limits of each type of risk are determined respectively (Tab. 6).

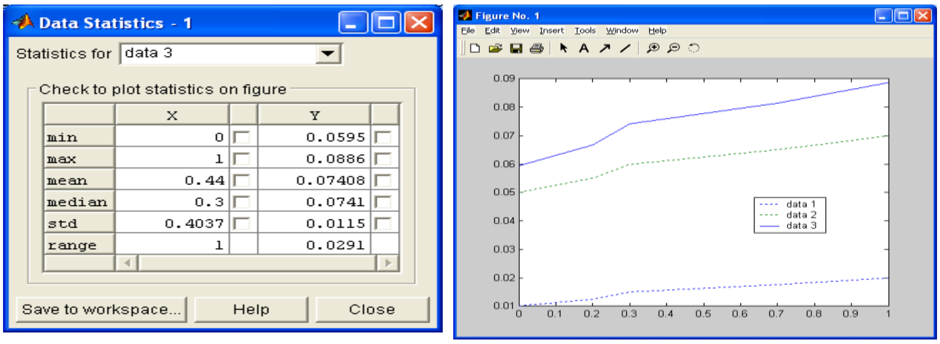
Table 5. Calculation of investments

№	Indicators name	Years			
		1	2	3	4
1	Costs for creation and operation of a prototype of the improved model of thermoplastic automatic machine, thousand euros	8,0			
2	Capital costs for partial reconstruction of thermoplastic automatic machine, thousand euros	142,5			
3	Expenditures on re-planning of the old case and carrying out repair and construction works in production of products from plastic, thousand euros	20,0			
4	Costs for equipment for plastic products production, thousand euros		45	81	87,75
Total		170,5	45	81	87,75

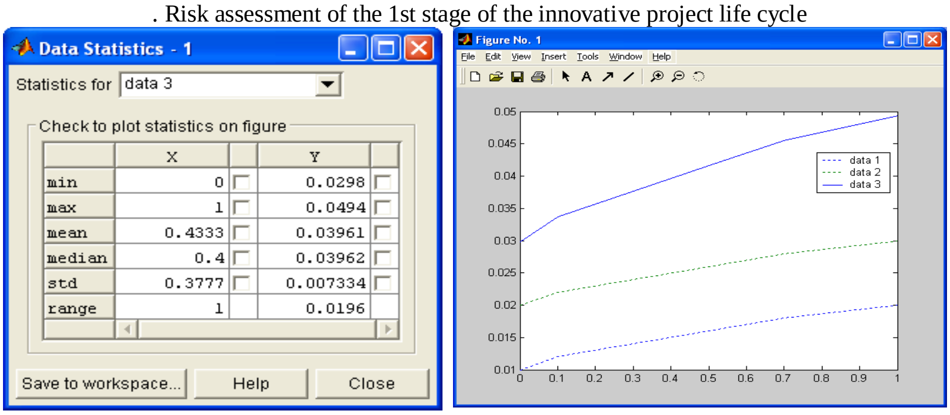
Table 6. Expert assessments of risks that arise at each innovation project life cycle stage

Stage contents	Risks of overspending $\underline{vc}_t^i \le vc_t^i \le \overline{vc}_t^i$		Risks of underfunding $\underline{ve}_t^i \le ve_t^i \le \overline{ve}_t^i$		Risks of overspending time on project stages realization $\underline{vt}_t^i \le vt_t^i \le \overline{vt}_t^i$	
	$\underline{vc}_t^i$	$\overline{vc}_t^i$	$\underline{ve}_t^i$	$\overline{ve}_t^i$	$\underline{vt}_t^i$	$\overline{vt}_t^i$
1. Marketing and research of market needs (identification of ideas from consumers)	0,01	0,02	–	–	0,05	0,07
2. Generating ideas from other sources	0,05	0,06	–	–	0,04	0,05
3. Selection of business ideas	0,0025	0,003	–	–	0,05	0,06
4. Development of goods concept and its check	0,005	0,006	–	–	0,02	0,05
5. Business analysis (analysis of production and sales opportunities)	0,005	0,006	–	–	0,05	0,06
6. Product development	0,01	0,02	–	–	0,06	0,07
7. Tests in market conditions (trial marketing)	0,005	0,006	–	–	0,05	0,06
8. Preparation and production of goods	0,02	0,03	–	–	0,06	0,07
9. Implementation	0,03	0,04	0,05	0,06	0,04	0,05
10. Growth	0,04	0,05	0,04	0,05	0,03	0,07
11. Maturity	0,02	0,03	0,05	0,06	0,06	0,07
12. Decline	0,01	0,02	0,02	0,03	–	–

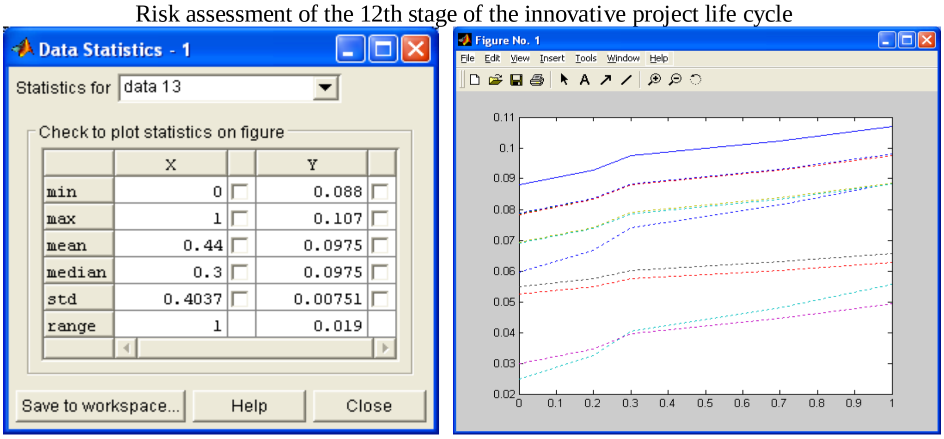
The results of the calculation of a complex innovative project risk assessment using fuzzy sets are shown in Fig. 1.



. Risk assessment of the 1st stage of the innovative project life cycle



Risk assessment of the 12th stage of the innovative project life cycle



Aggregate risk assessment of an innovative project

Fig. 1. The results of the calculation of a complex innovative project risk assessment using fuzzy sets

Taking into account the identified risks, the built simulation model has the form which is shown in Fig. 2.

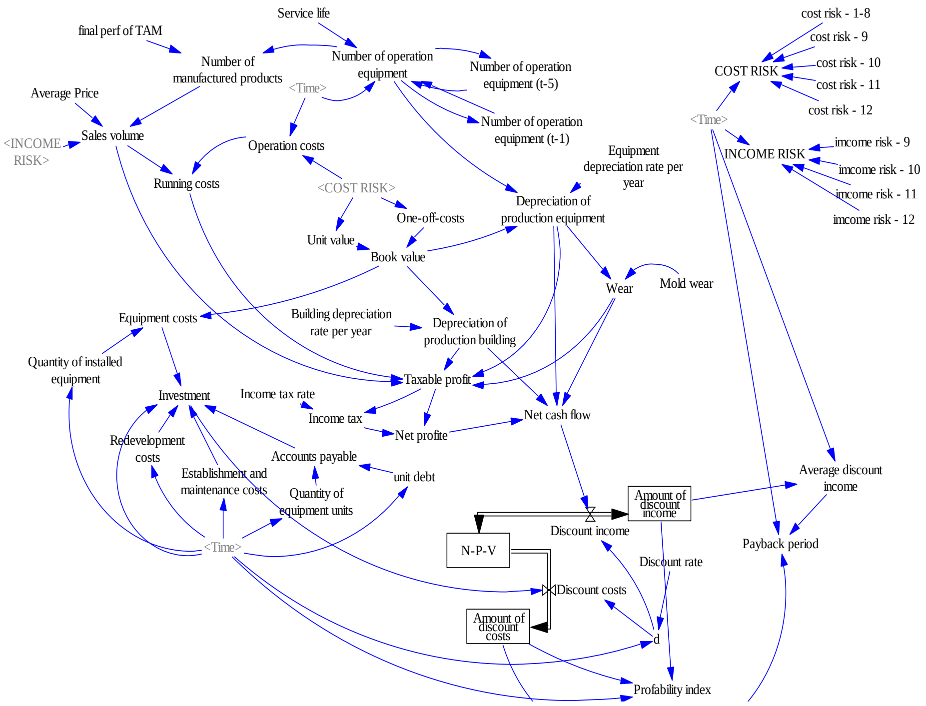


Fig. 2. Simulation model for assessing the innovative project effectiveness taking into account the risks

The final step is forecasting the development of the innovation project, which will identify the consequences of the combined impact of risk factors. To take into account the whole set of factors influencing competitiveness, in this research we recommend to use the method of strategic management - the method of " scenarios of future".

Let's investigate the system behavior in the case of different scenarios. To do this, we use the tools of scenario development. The simulation modeling and scenario approach are considered in Ramirez, Bañuls & Turoff (2015) and Katalevsky (2011).

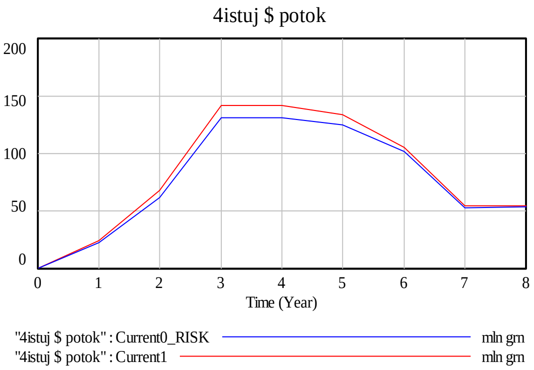
As mentioned earlier, each risk type has a lower and an upper limit. Under the events development scenario we will understand a combination of different risks values. The task of the research at this stage is to analyze the results of different scenarios and identify the most pessimistic and optimistic option. At zero values of risks, we obtain the basic version of the model. The optimistic option is the lower limits of risk at all stages of the life cycle. The pessimistic option would mean that the risk ratios are at the upper limit of their values. It is also advisable to consider mixed options, i.e. situations where the risks of overspending (increased costs) are minimal, and the risks of income loss are the maximum, or vice versa, as well as combinations with the absence of a particular risk type. Thus, we have 12 events scenarios, and their numerical results (Tab. 7).

The simulated values of indicators of the innovative project efficiency under the basic and optimistic scenario are presented in Fig. 3.

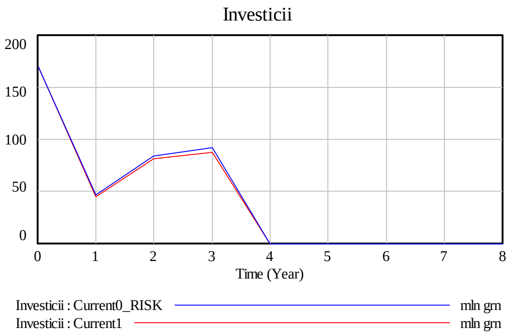
Table 7. Results of simulation experiments corresponding to risk scenarios

Experiment name	Net present value	Profability index	Payback period	Situation rank
1. Optimistic with random income risk (S12)	2,914	1,01	7,33	7
2. Optimistic with random cost risk (S11)	1,938	1,01	7,35	8
3. Pessimistic with random income risk (S10)	-2,441	0,99	7,45	13
4. Pessimistic with random cost risk (S9)	-1,077	1,00	7,42	12
5. Mixed (more risky in terms of income) (S8)	1,850	1,01	7,35	9
6. Mixed (more risky in terms of cost) (S7)	-0,252	1,00	7,40	11
7. Pessimistic (excluding income risk) (S6)	12,046	1,04	7,13	5
8. Pessimistic (excluding cost risk) (S5)	16,446	1,05	7,03	4
9. Optimistic (excluding income risk) (S4)	17,357	1,05	7,02	3
10. Optimistic (excluding cost risk) (S3)	19,588	1,06	6,97	2
11. The most optimistic (S2)	4,892	1,01	7,29	6
12. The most pessimistic (S1)	-3,247	0,99	7,47	14
Basic taking into account risk	1,419	1,00	7,36	10
Basic	32,498	1,10	6,71	1

Basic

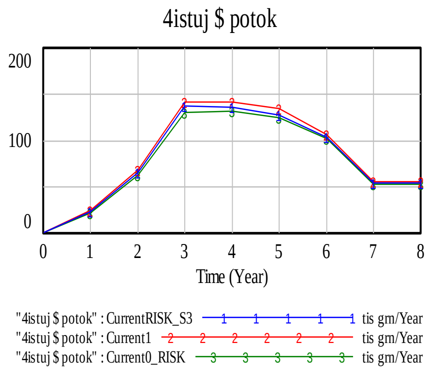


Discounted project revenue flow

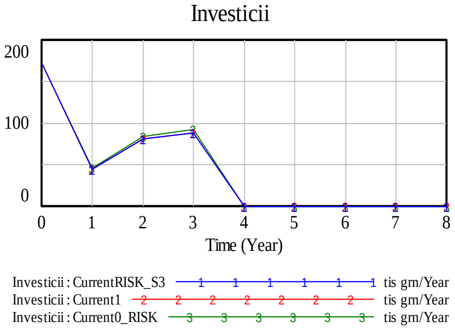


Discounted cost flow

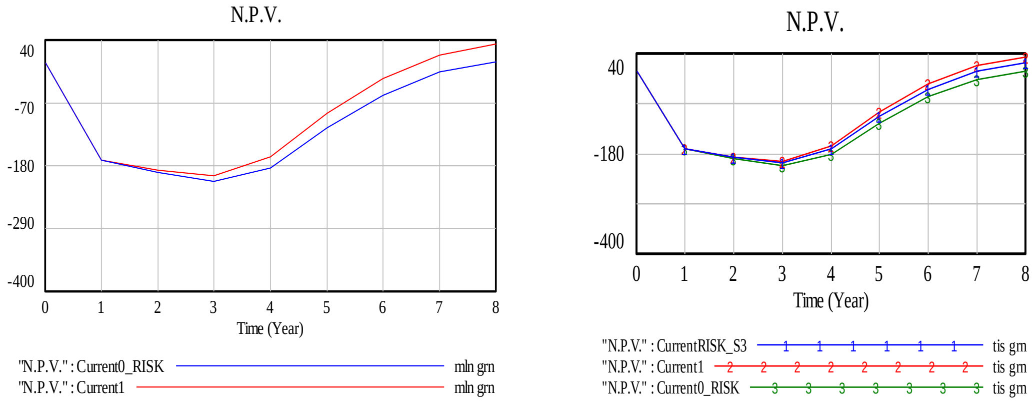
Optimistic without considering the risk of costs S3.



Discounted project revenue flow



Discounted cost flow



Net cash flow　　Net cash flow

Fig. 3. The values of efficiency indicators of the innovative project according to the baseline and optimistic scenario

As we can see, taking into account the risks, investments in the project will increase slightly, but insignificantly, while incomes at the stages of growth and maturity are decreasing. As a result, this leads to a decrease of the net present value. The deviation of investments as a result of the experiment was 1.47% upwards, net cash flow decreased by 4.34%. The indicator of net present income amounted to 1,419 thousand euro in comparison with 32,498 thousand euro for the basic model, i.e. the relative decrease was 95.6%.

The deviation of the yield index as a result of risk accounting was 8.75% downwards, and the payback period – 9.59% upwards.

Thus, risks of innovative projects significantly affects the results of the model. Therefore, it is important for the company to timely assess the impact of risk factors and develop measures to reduce and prevent them.

For an enterprise implementing an innovative project, the most desirable situation would be if there were no risky situations at the stages of the project life cycle. But in real life this situation is an exception, so we consider the basic option as ideal and unlikely.

Next in priority is the situation with minimal risks of overspending and no risk of income loss. In this situation, the company will receive significant profits with a slight extension of the project payback period and almost unchanged profitability index. The third priority is the reverse situation, where there is no risk of overspending costs. In this case, the company will have lower profits, payback period will increase to 7 years, the profitability index will decrease slightly.

Next in priority are situations with maximum values of one risk type and the absence of another. In such situations, the company receives profits over a longer period of time. Scenarios 2, 8, 11, 12 and baseline, taking into account the risk, are acceptable because the net present value of the return is greater than 0 and the payback periods are not too long. Other scenarios lead to losses as a result of the project, so the company must reject them.

The obtained generalizing criterion (rank coefficient) of efficiency of alternatives of realization, a certain stage of innovative project life cycle on all set of the influencing risks is adjusted to weighting factors of conformity and significance of this stage and the project to the general purposes and priority directions of enterprise innovative activity. According to the obtained values of the generalizing criterion and taking into account the weighting coefficients of compliance with the development goals, the most effective alternative scenario is determined. As a result of the application of the proposed algorithm, managers has a vector of possible alternatives for priority alternatives $y^{1,t} = \left(y_1^{1,t}, y_2^{1,t}, ..., y_n^{1,t}\right)$ that require certain managerial influences, which are arranged according to the values of the generalized criterion of efficiency and significance for the company and the investor.

The built scenarios, which unfold in a specific time interval, make possible to answer a number of important questions for forecasting:

– what are the trends of the components of the innovation project development;

– what factors, risks affect the implementation of these trends and to what extent;

– what problem situations and difficulties may arise in the development of a specific innovation project;

– what is the area of alternatives for management decisions regarding the enterprise innovative development;

– what are the expected consequences of certain management decisions.

The implemented set of models makes possible to compare all components of efficiency and risk, which determine the integrated aggregate level of project risk by components of life cycle risks, target project risks and scenarios depending on environmental factors and managers propensity to risk, and solves two main tasks:

– positioning of the real state of indicators of efficiency of the innovative project in comparative dynamic section on the basis of the three-level estimation caused by structural elements of risks;

– identification of possible and promising details and time horizons by stages of the project life cycle, critical paths and reserves, which make possible to achieve the main goal of improving the efficiency of innovative projects implementation.

IV Conclusions

The paper proposes a complex modeling toolkit, based on a simulation model for evaluating the innovative project effectiveness, which involves determining many indicators of project effectiveness and taking into account all types of risks that may arise at each stage of the innovation project life cycle. The ability to predict the risks of the project will allow the company to objectively assess the possible consequences and respond in a timely manner to the manifestations of their impact, to develop management decisions and to avoid undesirable consequences.

The algorithm based on the use of fuzzy inference rules with implementation in a simulation model is used to assess the impact of different system-forming risk groups and their cumulative integrated impact on the innovative project efficiency indicators. The proposed methodology of scenario forecasting based on the use of fuzzy logic and simulation improves the assessment of the risks impact degree on changes in the efficiency of the innovative project for development appropriate advanced measures to combat risks.

The proposed tools can be integrated into the procedural audit of innovative projects. Such research is systemically important for companies that want to gain a sufficient level of confidence in the project efficiency realization.

The tasks of the system methodology of complex audit of investment projects are complex diagnostics and determination of expediency of investment, efficiency of use of investment resources, validity of funds usage and investment risks assessment. Adequate complex assessment of the probability of risk and its mathematical interpretation is necessary to solve the problem of determining how acceptable this measure of risk is for a particular project and particular enterprise. Therefore, the problem of complex diagnostics and audit of innovative projects should be considered in further research and reflected in scientific papers, both in terms of methodology and instrumental research methods.

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