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Regional innovation programs' sustainability under risk and uncertainty

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**Regional innovation programs' sustainability under risk
and uncertainty**

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Regional innovation programs' sustainability under risk and uncertainty

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Abstract: Globalization in economy has been taking on an ever greater significance recently. Particularly important it is becoming now to such leading-edge technologies in economics as regional innovation processes. The current stage of the development of regional economies differs from the past ones in that the role of innovation programs acquires ever more importance and that forming and designing of such programs becomes now a much more independent process; all this has led to a situation where we have to revise our system of economic methods and ways of managing the risks of a regional innovation program. The existing methods and ways of risk assessment and risk management for innovations are to be complemented by new approaches reflecting the market changes and the advent of new financial instruments and stratagems. In this paper I investigate the issue of applying the system optimization method to the task of building the uncertainty/risk evaluation model for the management of a regional innovation program, proceeding from the method of limiting factor values which reduces the design value of an investment efficiency parameter to its critical limit for direct problems. As a result of my study, I propose the model of a regional innovation program's sustainability zone under risk and uncertainty, using the MATHCAT software.

Introduction

Currently the world community is going through globalization processes, whose first stage dates back to the dawn of civilization. It was as early as IV century B.C. that the first ever state in the Globe was formed and established. By early XX century the territory of the Earth had been finally divided between existing states. And about practically the same time (1990) did begin the second stage of globalization going on till the present day. By this we want to say that when globalization comes to its end, there will ensue effective dissolution of the world community only to give rise to a new cycle of the process. Based on the above, one can come to a conclusion that the process of globalization has a cyclic nature subject to well-known development laws, namely centralization and decentralization. The properties of economic cycles and their functioning are interestingly investigated and summarized in: Schumpeter J., 1939, pp.123-130. It seems to be quite clear that the globalization processes will not come to their respective end in the foreseeable future.

The holistic and cyclical nature of the development of international community allows us to view globalization, on the one hand, as a process, or, on the other, as a system at a certain development stage. The following works investigate how innovation processes unfold themselves in the context of globalization: Vambery R.G., Mayer P., 2012; Dreher A., 2006; Sirgy M.J., Lee D., Miller C., Littlefield J.E., 2004; Tsai C., 2007; Dosi G., 1988; Nikolova L.V., Rodionov D.G., Mokeeva T.V., 2014. If we presume that the global community is a system, then it may be said that it must perforce possess all attributes and properties of a system. This, in its turn, gives us grounds for singling out a subsystem in it - a geographical region having its own innovation program. The 'region' subsystem is also a system (Asheim B., Getleer M., 2004, pp. 121-125) comprising among other things a set of innovation programs (Bataev A.V. (2014); Nikolova L.V., Sergeev D.A., Omelaynenko A.R. (2014); Rodionov D.G., Fersman N. G., Kushneva O. A. (2014); Rodionov D.G., Guzikova L. A., Rudskay I.A (2014), Rodionov D.G., Rudskay I.A., Kushneva O.A. (2014). This thesis provides the author with enough grounds for handling not individual objects but systems with their appropriate emergent and synergetic dimensions.

Goal of the study: to substantiate the sustainability of a region's innovation programs under uncertainty and risk. In order to achieve the above goal we use the mathematical methods of system optimization: single-criterion methods and multi-criteria methods.

Methodology of the research

Risk management methods and procedures

Conventionally, there are two types of economic and mathematical methods of investment risk assessment for primal and reverse problems in risk management: quantitative and qualitative ones. To quantitative methods belong: design of experiment, spiral risk model, analog approach or conservative forecasts, risk-adjusted interest rate method, scenario analysis, decision tree method, sensitivity analysis, simulation approach. To qualitative methods belong: Delphi approach, SWOT analysis.

A review of research literature on the issue of applying mathematical models (Buyanov V.P., Kirsanov K.A., Mikhailov L.A., 2002; Stubbs W., Cocklin C., 2008; Short S.W., Rana P., Bocken N.M.P., Evans, 2012; Visnjic I.A., Bart V.L., 2012; Arkadiusz Borowiec, 2013.) demonstrates that not all the models have been substantiated mathematically and methodologically. As we know, a mathematical model is an approximated description of a certain class of phenomena denoted by mathematical symbols. By analysing a mathematical model we are able of getting an insight into the nature of objects under investigation. A mathematical model is undoubtedly a powerful tool for obtaining knowledge of the world around us as well as forecasting and controlling things. The models proposed by S.C. Myers and G.A. Pogue the "Longer" model of financial planning and the model of the best cash asset placement (capital planning problem) - are widely adopted by colleagues and used in the methods of sensitivity assessment and scenario analysis. Recently, other models have been getting popularity – those proposed by M.V.Gracheva (project efficiency assessment model with regard for risk-aversion measures; optimization of integrated risk cost model; optimization of integrated internal and external risk costs model); these are also used for sensitivity analysis and scenario analysis tasks. The complexity of calculating the probability-simulation models of assessment, management and optimization proposed by A.G.Novokreshchenov – based on the method of simulation modelling – has led to a situation where such models are very rarely applied to the practical problems of investment. Such models can be successfully applied to the tasks of risk assessment and innovation project management, along with risk assessment and management of regional innovation programs. Uncertainty and risk belong to the objective side or aspect of the innovation process; they are its integral parts bearing on all phases and milestones of its implementation.

Suppose there is a hypothetical model of an innovation process which is a system made up of two interplaying sub-systems: the sub-system of risks composed of risk factors, and the sub-system of conditionally defined implementation stages. The combination of the sub-systems is essentially a model of implementation of real innovations. regional innovation process is also defined as a combination of these sub-systems and can be described as a closed-loop process (cycle), i.e. an innovation system that is subject to the laws of the theory of optimal control of systems. The innovation system is a range of programs – of all scales and sizes - whose implementation implies risks both while solving current and long-term investment tasks. The total variety of approaches to the study of systems can be broken down into analysis and synthesis, which, in their turn could be grouped as follows: analysis – functional or structural, synthesis – emergent (that defines coherence of a system) or synergetic (co-acting, multiplicative effect). The *emergent* properties of investment are linked to the fact that the system acquires new characteristics or qualities belonging to neither of the sub-systems (elements). The rise of *emergent properties* and *emergent* risks in the system can be used as a basis for the method or procedure of defining the systemic qualities of this investment object (see: Buyanov V.P., Kirsanov K.A., Mikhailov L.A., 2002). To reveal *emergent risks* (risk-factors) is one of important tasks in a study; however, it leads solely to the ascertaining of the fact that the interplaying objects begin to acquire new properties. In part this question can be answered with the help of *synergetics* – a science studying the processes and laws of self-organization. The science that does not take systemic risks into account assumes that by an external action upon an object you can always get the desired effect, i.e. transform the object in the way a researcher wants it to. Yet, experience demonstrates that in most cases this is more than problematic. Difficulties related to the process of innovation risk management can be accounted for by the fact that we do not have unambiguous data on the mechanisms regulating certain inner processes, which makes the author of this study limit it to the description of risks as final functional relations.

Given more factors to take into account, logic algebra methods are used in order to make a preliminary conclusion concerning the factors' significance. First we have to quantize the working variation ranges into individual levels and then, by the method of Boolean functions' minimization, build a Boolean model of the system. At the next step we solve the task of the informal interpretation of the Boolean models.

While proceeding from the qualitative to quantitative analysis of the system's structure, we have to check if the previous results – both quantitative and qualitative – can be used for the evaluation of the system under investigation. There are various methods of such verification to be used here; they differ: by the degree of isomorphism, by the method of choosing the verification rule, by the tools used to find this verification rule. In its simplest form, structural analysis investigates a definite structural component of the system (in our case it means risk-factor). What we actually investigate using this approach are the properties of structural components at different levels when building the model of risk management. The approach I propose here allows us to substantiate the systemic nature of the assessment and management of regional innovation process risks and to create a framework for further studies. To build a model of regional innovation program risk management we have to identify the methodological, procedural and operational principles that can coherently bind together various interests at the macro- and micro-level existing in the region under investigation.

1. The methodological principles, i.e. the ones which determine conceptual fundamentals for regional investment, are the most general and – which is even more important – independent from the specific nature of the type of risk being investigated (they can be even invariant in relation to the concrete semantics of the goal and of value paradigms). For the purpose of shaping the methodology of investment in the region we apply the optimal system control theory and the methods of system analysis.

The methodological fundamentals also imply taking into account the modern specificities of investing that help us substantiate new approaches to the task of building a model of innovation risk management in a given region. The following rules underlie this principle:

- similarity of risks – this means that each participant's perception of risk is the same as that of all others';

- positiveness of risks – this means that the integral risk index lies within the acceptable threshold. In innovation programs this principle is generally associated with the principle of efficiency/performance;

- objectivity of risks – this means that for risk assessment we have to correctly formulate the structure and properties of the changing object;

- correctness of risks – this means that the risk assessment procedure is subject to certain formal requirements, such as:

a) accumulative monotonicity: meaning that - within a certain exponent range - if activity intensifies the risk also grows; at the same time in boundary zones uncertainty is measured qualitatively;

b) non-direct proportionality – this means that the growth of risk is not directly proportionate to the intensification of activity (in the given exponent range);

c) transitivity – this means that if situation "a" is less risky than situation "b", and situation "b" is less risky than situation "c", then situation "a" is less risky than situation "c";

d) additivity – this means that risk is equal to the sum of particular risks:

- risk integration – this means that taken as a whole risks have to form a closed system;

- interdependency of risks – this means that when some risks arise other risks also arise due to interaction effects.

2. Procedural principles – i.e. the ones directly associated with the content of the innovation program, its specific characteristics, implementation, and real situations. The following rules underlie this principle:

- dissonance of risks – this means that each new project impacts the innovation program in its own specific way; the stronger is the dissonance of the new project, the higher is the risk;

- different perception of risks – this means that different projects making up the program have their risks, which determines the incongruity of interests of project participants and differing attitudes towards possible damage or loss;
- dynamism of the risks constituting an innovation program means that procedural support takes into account the changing nature of risks;
- risk coherence in the innovation program means that prevention processes have to be coordinated with other processes, when risks arise.

3. Operational principles, i.e. those linked to the availability, reliability and unambiguity of information, and tools at hand to process it.

- modulability of innovation *program*' risks determines a situation when the arising risks can be described with the help of a model;
- simplifiability of innovation *program's* risks tells us that while assessing risks we choose the method which is most simple from the calculation or computing point of view.

As a result, I have framed a methodology for investigating the problem of sustainability of regional innovation programs under uncertainty and risk. I also identify and define methodological, procedural and operational principles relying on the rules which were used for building the model of risk management.

System optimization of risk for a regional innovation program

Risk management optimization theory - fundamentals

The investment sensitivity method is a single-criterion optimization problem, which means that for its implementation only one efficiency function is used, namely the factor impacting innovation efficiency. I propose to consider the further development of sensitivity analysis i.e. to move from single-criterion analysis to multi-criteria one on the basis of S.Pontryagin's analytical procedure, i.e. to solve limited variational problems occurring when we have to optimize control and management in dynamic systems. The analytical procedure proven by S. Pontryagin is used for substantiation of the method of sustainability of a regional innovation program under uncertainty and risk. The method of defining investment sustainability ensures the calculation of the limiting factor values that impact investment efficiency when solving direct problems.

The theory of forming a regional innovation program and its properties help us optimize innovation risks and manage them. One of the particularly troublesome tasks pertaining to making an innovation program of a region is the necessity of using synthesis for the assessment of innovation efficiency. A regional innovation program is a multifaceted dynamic system for the management of whose risks many risk criteria have to be used (risk-factors). In some cases these risk-factors can be reduced to one risk, thus returning the solution procedure to the well-known method of single-criterion optimization. The simplest method of such reduction is the so called *weighting of criteria*. If $f_1(x), \dots, f_n(x)$ are objectives expressing the values of the criteria being used, then for each of them – subject to its impact upon investment efficiency – we choose a positive weighting factor λ_i . The procedure of weighting criteria (objectives) $f_1(x), \dots, f_n(x)$ consists in replacing them by one and only one criterion (objective) $f(x) = \lambda_1 \cdot f_1(x) + \dots + \lambda_n \cdot f_n(x)$ (Tchernorutsky I.G., 2001, p. 34-40).

However, for the purpose of managing the risks of an innovation program such reduction turns out to be practically impossible, therefore in the process of optimization we have to deal with a *vector* efficiency function (*multi-criteria*). At the same time the permissible region M can change during optimization. More than that: its purposeful change is the substance of the process of optimization for this class of problems.

Since the laws of possible changes in the permissible region M are normally defined by a system of models, the approach to optimization problems I am describing here is called *system approach*. Within the framework of the system approach, the change of limits defining the permissible region in the space of individual parameters takes place as a result of a sequence of solutions we choose from a discrete set of possible solutions, where this set of solutions at the beginning of the optimization

process can be defined incompletely and is being enlarged during the development and implementation of the innovation program.

One of very characteristic formalized statements of the problem of system optimization is the 2-criteria analysis. Let us suppose that by choosing the values of these criteria we can uniquely define the appropriate solution. In other words, the desired solution is being sought directly in the space K of optimization criteria that we will denote x_1 and x_2 .

The solution process begins when in the defined space K we choose a point A_0 with coordinates a_0, b_0 — the desired solution of the problem. Then we build initial constraints $F_1^{(0)}(x_1, x_2) \geq 0, \dots, F_n^{(0)}(x_1, x_2) \geq 0$ which define the initial permissible region P_0 . By a direct check we define whether point A_0 belongs to region P_0 . In the former case, theoretically, we can use the conventional (classical) procedure of optimization by either one of the x_1, x_2 , criteria or by their combinations.

With the system approach, however, a much different method is used, namely: in accordance with model M at a higher level regulating the choice of criteria, point A_0 is taken out of permissible region P_0 after that we single out the constraints which do not hold for point A_0 (in this case those will be $F_3^{(0)}$ and $F_4^{(0)}$). Turning to models M_3 and M_4 , which lay down these constraints, we consider — in the dialog mode — the solutions that can change the appropriate constraints in the desired direction (if possible). The "desired" direction in this case is considered to be the one which decreases the absolute value of negative residuals $F_i^{(0)}(a_0, b_0)$ (in the case under consideration it is $F_3^{(0)}(a_0, b_0)$ and $F_4^{(0)}(a_0, b_0)$).

Here we should bear in mind that in many cases the F_i constraints turn out to be interrelated, so the change of one of them leads to a change in a certain number of other constraints. The control of the solution choice needed to change the constraints is defined here by the minimization of a penalty function $g_0(a_0, b_0)$. For this penalty function the maximum absolute value of negative residuals $\lambda_i F_i^{(0)}(a_0, b_0)$ is usually chosen (where λ_i — certain positive weight coefficients). If there are no such residuals, then, by definition, $g_0(a_0, b_0) = 0$. As a result of such control, there emerges a range of solutions R_1, \dots, R_m , each leading to the decrease of the penalty function value that we shall denote $g_m(a_0, b_0)$ after m solution.

Each of the accepted solutions - by changing the constraints - brings about the appropriate change in the permissible region. Let us consider two of such changes: the first one changes limits $F_3^{(0)}, F_2^{(0)}$, replacing them, respectively, by limits $F_3^{(1)}, F_2^{(1)}$; the second one affects only one constraint $F_4^{(0)}$ replacing it by constraint $F_4^{(1)}$. The resulting permissible region P_2 is limited by lines $F_1^{(0)}, F_2^{(1)}, F_3^{(1)}, F_4^{(1)}$, while the corresponding penalty function value is equal to $g_2(a_0, b_0)$. Advance choice of the final permissible region is impossible due to the fact that the sequence of regions P_0, P_1, \dots cannot be ordered by embedding. In addition to this, the outstanding complexity of making new limits does not allow us to do it beforehand, because too much unnecessary work would be required to be done to change insignificant constraints. If $g_2(a_0, b_0) \neq 0$ and there are no solutions leading to further decrease in the value of the penalty function, then we are returned to the higher model M that controls the choice of the desired solution $A(a, b)$. By successive solutions D_1, D_2, \dots, D_k to change the initial solution of the problem $A_0(a_0, b_0)$ it is replaced by $A_1(a_1, b_1), \dots, A_k(a_k, b_k)$ till one of the next points $A_k(a_k, b_k)$ finds itself within the permissible region ($k = 1$). Solutions for change are chosen from the allowable set of solutions with the aim of minimizing the penalty function. This procedure seems to be very close to the classical optimization apart from the fact that steps are chosen not arbitrarily but in compliance with the permitted (by model M) solutions. After point A_k gets into the final permissible region P_m we can use an additional optimization procedure by various combinations of criteria x_x and x_2 within this permissible region. This procedure differs from the classical one by the only fact that the choice of optimization steps is not arbitrary but is controlled by the higher level model M . If further improvement of the chosen criterion is hindered by certain limitations which we can change in the desired direction, then the optimization process can be continued through the inclusion of successive limitation-change solutions into it. The most important characteristic of system optimization retained in all approaches to the problem is - apart from multi-criteriality and a possibility to change the permissible region - the interaction of models on different levels. In this case, as part of structural analysis, this is system interaction: of the risk system composed of risk-factors, and of the system of implementation of the regional innovation program — by a model on the M level. A single-valued solution of the problem - through the choice of the values of all optimization criteria - cannot be used here for the purposes of substantiation of the regional innovation program risk management model,

because there is no uniqueness to the solution of this problem. The space where the solution is being sought, may have other coordinates in addition to the ones matching optimization criteria. The optimization procedure described above becomes complicated due to the fact that points $A_1 (a_1, b_1)$ are replaced by hyperplanes – i.e. stable investment zones. Definition of the penalty function becomes more complicated too: we can take as this function, for instance, the distance between a chosen hyperplane and the next permissible region in the space with defined contractions (stretchings) along the axes corresponding to optimization criteria – change factors for the limiting values of the sustainability model.

The assessment of risks' (risk-factors') impact upon the efficiency of the innovation program has been done on the basis of a number of integral indexes, such as: net present value (NPV_T), profitability index (PI_T^d), internal rate of return (IRR), payback period (PP_T^d). Efficiency indicator's sensitivity to the change of risk-factors has been assessed by defining the indicator's elasticity for this specific factor. Let us denote the risk-factors by q_1, \dots, q_n ; their values we can obtain from the $NPV(q_1, q_2, q_3, \dots, q_n)$ formula ≥ 0 .

Regional innovation program sustainability model.

The model of sustainability of a region's innovation program can be defined as an assembly of risk-factor value sets $q_1, q_2, q_3, \dots, q_n$, satisfying the system of inequalities:

$$NPV(q_1) \geq 0; NPV(q_2) \geq 0; NPV(q_3) \geq 0; \dots; NPV(q_n) \geq 0.$$

If conditions applied to the value of the NPV indicator are met, then the values of indicators PI_T^d , IRR, PP_T^d will change accordingly.

Consider building a sustainability zone for an innovation program in a three-dimensional space with, for instance, four risk-factors affecting the situation.

- I. Define the maximum value by which the impacting risk-factors can increase.
- II. Then define how the sustainability zone of an innovation project changes if during the implementation of the innovations the desired rate of return on capital for an investor (r) changes.
 - I. Now assume that the results of the innovation program changed because:
 - the return on capital changed by several % ($-q_1$);
 - the investment capital (IC_{1t}) increased by several % (q_2);
 - the investment capital (IC_{2t}) increased by several % (q_3);

Calculate the factor limiting values with which the innovation program will have a cumulative break-even point.

Defining the limiting value of the return on capital change (q_1)

In a situation when the innovation program will have the cumulative break-even point, i.e. when the NPV will be equal to 0,

$$NPV = -\sum_{t=0}^T \frac{IC_t}{(1+r)^t} + \sum_{t=1}^T \frac{CF_{it} - CF_{o_t}}{(1+r)^t} \quad (1)$$

Let us equate expression (1) to 0.

To find the limiting value of the change of return we transform formula (1) by substituting the changes of return (q_1) into it (2):

$$\sum_{t=1}^T \frac{CF_t \left(1 + \frac{q_1}{100}\right)}{(1+r)^t} - \sum_{t=0}^T \frac{IC_t}{(1+r)^t} = 0 \quad (2)$$

By making the transformations we obtain the q_1 (3):

$$q_1 = \left[1 - \frac{\left(\sum_{t=0}^T \frac{IC_t}{(1+r)^t} \right)}{\left(\sum_{t=1}^T \frac{CF_t}{(1+r)^t} \right)} \right] * 100 \quad (3)$$

The resulting formula can be further simplified and the q_1 (4) calculated:

$$q_1 = \left(1 - \frac{DIC_t}{PV} \right) * 100 \quad (4)$$

Defining the limiting value of the change of equipment cost (q_2)

For this we transform formula (1) by substituting the capital investment change (q_2) into it, and then calculate the limiting value of the change of investment cost (IC_{1t}) of the innovation program (5):

$$q_2 = \frac{PV - IC_t}{IC_t} * 100 = \frac{NPV}{IC_t} * 100 \quad (5)$$

Defining the limiting value of the change of the equipment installation cost (q_3)

For this we transform formula (5) by substituting the capital investment change (q_3) into it, and then calculate the limiting value of the change of investment cost (IC_{2t}) of the innovation program (6):

$$q_3 = \frac{PV - IC_t}{IC_{2t}} * 100 = \frac{NPV}{IC_{2t}} * 100 \quad (6)$$

The results of the calculation are presented in Table 1.

Table 1. Impact of the limiting values of factor changes upon the efficiency indicators of an innovation project

Parameter Factor in %	change, NPV (thousand roubles)	r	PI	DPP y. m., d.
q_1 , %	0	r_{BH}	1	T
	0	r_{BH}	1	T
q_2 , %	0	r_{BH}	1	T
	0	r_{BH}	1	T
q_3 , %	0	r_{BH}	1	T
	0	r_{BH}	1	T

Formation of the sustainability zone for a region's innovation program

The practical implementation of the theory of system optimization of risk management is done by the example of the assessment of risks of a particular regional innovation program.

Defining sustainability of the innovation program using specific data, such as:

IC = 90 thousand currency units; $CF_{t1} \dots CF_{t6}$: 10, 20, 30, 30, 40, 51 thousand currency units; project implementation period T = 6 years, calculation time-step t = 1 year.

1. We define the formula of discount rate change (r) by extrapolation (see the text of the program).

2. We shape the sustainability zone for the innovation program using four risk-factors: cash flow - CF; capital investment - IC_{1t} , capital investment - IC_{2t} , discount rate - r.

(Carried out in the mathematical modelling software package MATHCAD).

Implementation program:

$$t := 0..6$$

$$CI := 900000$$

$$D := \begin{bmatrix} 0 \\ 10000 \\ 20000 \\ 30000 \\ 30000 \\ 40000 \\ 51000 \end{bmatrix},$$

$$T := 6$$

$$e(t) := 0.1 + 0.01t^2 + 0.05 \ln(t + 1)$$

$$NPV(t) := \sum_{k=0}^T D_k \cdot \frac{1}{(1 + e(t))^k} - CI$$

$$x := 0,$$

$$t := 0..6,$$

$$CI := 90000$$

$$D := \begin{bmatrix} 0 \\ 10000 \\ 20000 \\ 30000 \\ 30000 \\ 40000 \\ 51000 \end{bmatrix}$$

$$NPV(E, d, q) := \sum_{t=0}^T D_t \cdot \frac{1+d}{(1+E)^t} - CI \cdot \frac{(1+q)}{(1+E)}$$

$$a := 0 \quad a0_t := \text{root}(NPV(t,0,a,0), a)$$

$$a := 0$$

$$q := 0 \quad q0_t := \text{root}(NPV(t,0,0,q), q)$$

	0
0	-0.252
1	-0.228
2	-0.202
3	-0.168
4	-0.125
5	-0.075

$$a0 =$$

	0
0	0.494
1	0.434
2	0.371
3	0.296
4	0.21
5	0.119

	0
0	1.415
1	1.244
2	1.062
3	0.847
4	0.602
5	0.34

$s0 =$	6	-0.017
	7	0.046
	8	0.112
	9	0.179
	10	0.245

	6	0.026
	7	-0.064
	8	-0.147
	9	-0.222
	10	-0.289

$q0 =$	6	0.074
	7	-0.183
	8	-0.422
	9	-0.637
	10	-0.827

$$A^{(0)} := s0$$

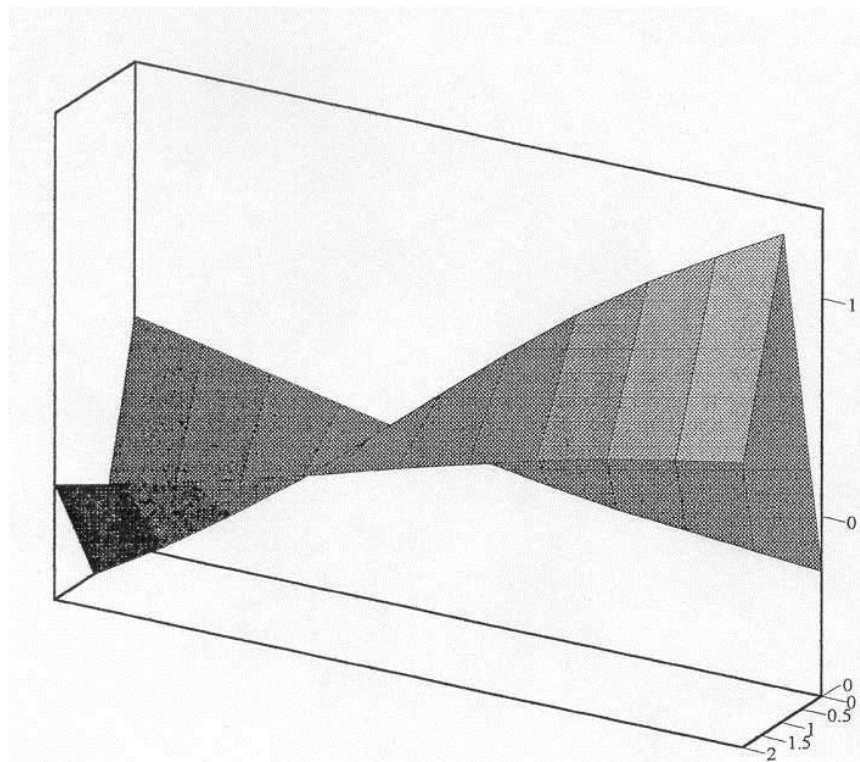
$$A^{(1)} := q0$$

$$A^{(2)} := a0$$

As a result, we have a model of innovation program of a region, in the process of whose implementation the discount rate (r) changes every year.

On Picture 1 you can see 12 models of regional innovation program sustainability consolidated into one image: lower part – 7 models – is the domain of efficiency (inside) the innovation program of the region; upper part of the image – the domain where this innovation program is inefficient (it is added here to make our study more comprehensive).

The analysis carried out by the author has allowed her to define the innovation program of a region as a complex dynamic system whose risk management is possible if the method of sustainability assessment is used; the method is based on the risk management model mathematically substantiated by S.Pontryagin.



$$x = 0.25$$

$$Tirr(s, a, q) = \text{root}(NPV(x, s, a, q), x)$$

$$Tirr(0,0,0) = 6.281$$

$$IRR(s, a, q) := e(Tirr(s, a, q))$$

$$IRR(0,0,0) = 0.594$$

Fig. A. Sustainability zone of an innovation project

Conclusion

The study offers the results of application of the system optimization method to the task of shaping an uncertainty/risk assessment model for the management of a region's innovation program; the method is based on the procedure that assumes defining the limiting values of the factors that bring the design value of a corresponding investment efficiency criterion to its critical limit while solving direct problems. As a result of my study, I propose the model of a regional innovation program's sustainability zone under risk and uncertainty, using the MATHCAT software.

The assessment of risks' (risk-factors') impact upon the efficiency of the innovation program has been done on the basis of a number of integral indexes, such as: net present value (NPVT), profitability index (PITd), internal rate of return (IRR), payback period (PPTd). Efficiency indicator's sensitivity to the change of risk-factors has been assessed by defining the indicator's elasticity for this specific factor. The model of sustainability of a regional innovation program is defined as an assembly of value sets of risk factors $q_1, q_2, q_3, \dots, q_n$, satisfying the system of inequalities:

$NPV(q_1) \geq 0; NPV(q_2) \geq 0; NPV(q_3) \geq 0; \dots; NPV(q_n) \geq 0.$

Most generally, point sets of arbitrary form may be involved instead of hyperplanes. Problem formulations are possible where criteria values in these sets are defined ambiguously, while for the definition of more or less desirable solutions we have to define appropriate weight functions in these sets (by a model of the higher level M).

The most important characteristic of system optimization retained in all approaches to the problem is - apart from multi-criteriality and a possibility to change the permissible region - the interaction of models on different levels. In this case, as part of structural analysis, this is system interaction: the risk system composed of risk-factors, and the system of implementation of the regional innovation program - by a model on the M level.

When considering a large number of risks (risk-factors) impacting the efficiency of a region's innovation program and subject to analysis and control, a hyperplane taken in the three-dimensional space tends to a one-sheet hyperboloid.

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