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QUALITY SIMULATION OF RISK CONTRIBUTING FACTORS IN HIGH TECHNOLOGY ENTERPRISES AND PRODUCTIONS

Here we consider the planning high technology enterprise activity under the conditions of uncertainty of the economic situation and emerging risks associated with innovation in production. The qualitative simulation procedure is applied that is based on subjective (expert) estimates and multilevel analytical networks with gradations of possible risks. For the analysis of a complex of factors, which may be the source of risk situations in the activity of enterprises and industries involved in innovative activities the qualitative simulation procedure is used that allows to compose recommendations that represent a variety of solutions for the decision maker.

Keywords: *risk contributing factors, qualitative simulation, analytical networks, hierarchy levels, matrix, pairwise comparison.*

Problem statement

Under conditions of growing variability and uncertainty of the economic situation there is ambiguity and incertitude in obtaining the resulting effect, and consequently there is a risk that is a threat of failure, contingent losses. Most of all this situation affects the activities of high technology enterprises and industries producing various types of innovation (innovation – product, innovation - process, social innovation, and others.). The problem of economic risk modeling and forecasting in such enterprises lies in poor predictability of impact of many different risk contributing factors [2, 3]. This indicates the lack of information about the probabilities of these factors occurrence that is a prerequisite for the application of qualitative simulation procedures of risk situations on the basis of subjective (expert) estimates. Such problems are related to the decision making problems under uncertainty and emerge when strategic predicting, planning, resource allocation, and others.

Analysis of recent researches and publications

Analysis and experience of expert evaluations showed high effectiveness of the methods based on the theories of analytical hierarchy of AHP (Analytical Hierarchy Process) and analytical networks of ANP (Analytical Network Process) T. Saaty [6,7, and others] and that got wide use for solving the problems of multi-criteria alternatives. The hierarchy analysis method (HAM) is a mathematical tool of the system approach to the agreed decision problem in the multicriteria environment where the objects under study and criteria of their estimation can not be measured in a quantitative form. In addition it has a number of advantages that give a universal character in terms of areas of practical applications [1].

However it should be noted that HAM is based on the fact that the importance of factors affects the priorities of their development scenarios but without considering the importance of alternatives may also affect the criteria priorities (factors). This aspect completes the analytical network method (ANM) which is the further development of AHM and takes into account feedbacks and interactions. ANM is based on building the quality network model consisting of a number of clusters that describes both the influence of factors on the system under study and the interaction of the elements that complete these clusters.

The purpose of the article is to describe the procedures of quality modeling the risk contributing factors that affect the activity of high technology enterprises and production using the analytical network method.

Statement of the base material

Issues of description and classification of high technology production risks in innovation activity are covered in a number of papers for example [4,5] that give such risk classes as organizational, legal, industrial and technological, financial and others in generalized form.

At the same time such approach is not only possible as in practice there may be many individual problems that require identification and analysis of additional risk contributing factors (criteria) for their solutions.

Let us consider the problem of quality simulation of high technology enterprises activity, and determine the financial indicator "PROFIT" as a pilot indicator. The structure of this problem represents a network consisting of four clusters (Fig. 1). At the top level of network there are factors that affect the profit state: "PORTFOLIO OF ORDERS" and "SALES OF MAIN PRODUCTS". Each of these factors, in turn, is described by a number of factors (parameters), which are located on the second level of the hierarchy. The third level shows 3 gradations of possible risks [4]:

1. Acceptable risk that is characterized by financial losses not exceeding the total profits of the enterprise.

2. Critical risk that is characterized by financial losses not exceeding the zero bracket amount of the enterprise.

3. Catastrophic risk is characterized by financial losses for which there is a partial or complete loss of equity capital, and may be accompanied by loss of borrowed capital. Since both of the main factors (cluster 1) are exposed to risk their relative importance should be set for each of three risk gradations.

Thus, in the structure of network instead of a single purpose which is usually present at the highest level, the alternative risk gradations use to compare two main factors. It causes the occurrence of the feedback in network structure in which the priorities of top-level factors are determined relative to the lower-level elements (cluster 4), thereby forming a cycle [7].

The next stage of ANM implementation is to construct matrices of pairwise comparison and formation the supermatrix on this basis. In this case the results of the possible decision making depends on the quality of expert judgements.

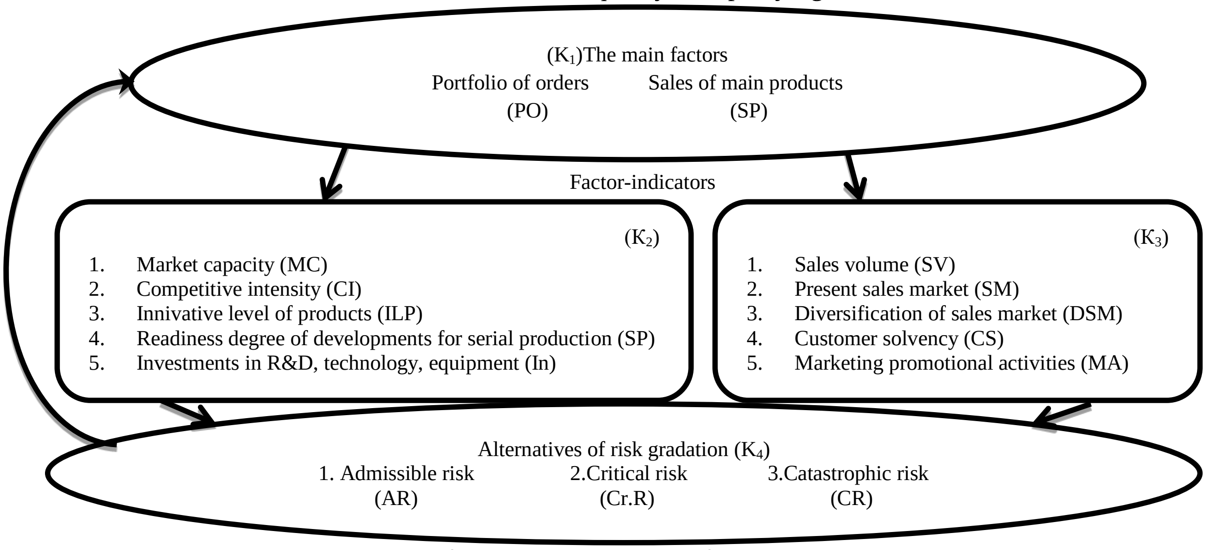

Figure 1. The Structure of the network problem of risk situations quality simulation in high technology productions

For this network structure (Figure 1) the supermatrix of pair comparisons can be written as follows:

$$W = \begin{pmatrix} & & K_1 & K_2 & K_3 & K_4 \\ & & k_{11}k_{12} & k_{21}k_{22}k_{23}k_{24}k_{25} & k_{31}k_{32}k_{33}k_{34}k_{35} & k_{41}k_{42}k_{43} \\ K_1 & \begin{matrix} k_{11} \\ k_{12} \end{matrix} & W_{11} & W_{12} & W_{13} & W_{14} \\ K_2 & \begin{matrix} k_{21} \\ k_{22} \\ k_{23} \\ k_{24} \\ k_{25} \end{matrix} & W_{21} & W_{22} & W_{23} & W_{24} \\ K_3 & \begin{matrix} k_{31} \\ k_{32} \\ k_{33} \\ k_{34} \\ k_{35} \end{matrix} & W_{31} & W_{32} & W_{33} & W_{34} \\ K_4 & \begin{matrix} k_{41} \\ k_{42} \\ k_{43} \end{matrix} & W_{41} & W_{42} & W_{43} & W_{44} \end{pmatrix} \quad (1)$$

W_{ij} elements in W supermatrix are called blocks and represent matrices as follows (2):

$$W_{ij} = \begin{pmatrix} w_{i1j1} w_{i1j2} \dots w_{i1jn} \\ w_{i2j1} w_{i2j2} \dots w_{i2jn} \\ \dots \quad \dots \quad \dots \quad \dots \\ w_{inj1} w_{inj2} \dots w_{injn} \end{pmatrix} \quad (2)$$

Each column in W_{ij} matrix represents a priority vector characterizing the influence of the i-th network component elements on the j-th component elements. The absence of such influence is defined in supermatrix by zeros. The priority vector formation is carried out by pair comparison between the components, their elements or between the components and elements. Herewith a series of matrices with reverse symmetry properties is forms. For example, the procedure of forming the priority vector for K2 network component (cluster) (Fig. 1) can be represented by the following scheme:

$$K_2\begin{pmatrix} & k_{21} & k_{22} & k_{23} & k_{24} & k_{25} \\ k_{21} & a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ k_{22} & a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ k_{23} & a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ k_{24} & a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ k_{25} & a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix} \Rightarrow \quad \Rightarrow \begin{cases} \sqrt[5]{a_{11}a_{12}a_{13}a_{14}a_{15}} = d_1 \\ \sqrt[5]{a_{21}a_{22}a_{23}a_{24}a_{25}} = d_2 \\ \sqrt[5]{a_{31}a_{32}a_{33}a_{34}a_{35}} = d_3 \\ \sqrt[5]{a_{41}a_{42}a_{43}a_{44}a_{45}} = d_4 \\ \sqrt[5]{a_{51}a_{52}a_{53}a_{54}a_{55}} = d_5 \end{cases} \Rightarrow \qquad (3)$$

$$\Rightarrow (d_1 + d_2 + d_3 + d_4 + d_5) =$$

$$D \Rightarrow \left(\frac{d_1}{D} = w_1; \frac{d_2}{D} = w_2; \frac{d_3}{D} = w_3; \frac{d_4}{D} = w_4; \frac{d_5}{D} = w_5\right) \Rightarrow$$

$$\Rightarrow W = (w_1, w_2, w_3, w_4, w_5) - \text{is a priority vector}$$

Here are: a-numbers defining the fundamental scale gradations (Miller's numbers) [7];
$D=(d_1, d_2, d_3, d_4, d_5)$ is K_2 matrix eigenvalues vector;
d_1, d_2, d_3, d_4, d_5 are the eigenvalues;
w_1, w_2, w_3, w_4, w_5, are the priority weights obtained by normalizing as d_i/D, i=1,n.

Let us consider the network analysis procedure through the pair comparison between the singled out factors and risk graduations and the subsequent formation of a number of matrices and the supermatrix. The results of this comparison are presented in the tables (1-7).

Table 1. The matrix of pair comparisons between factors regarding the main factor "Portfolio of orders"

The portfolio of orders (PO)	MS	CI	ILP	SP	In	Priority vector
Market capacity (MC)	1	3	1/5	1/2	1/3	0,11
Competitive intensity (CI)	1/3	1	5	1/2	1/3	0,13
Innivative level of products (ILP)	5	1/5	1	1	1/5	0,12
Readiness degree of developments for serial production (SP)	2	2	1	1	1/3	0,18
Investments in R&D, technology, equipment (In)	3	3	5	3	1	0,46

Table 2. The matrix of pair comparisons between factors regarding the main factor "Sales of main products"

Sales of main products (SP)	MS	CI	ILP	SP	In	Priority vector
Sales volume (SV)	1	1/3	1/4	1/7	1/2	0,05
Present sales market (SM)	3	1	1	1/5	1	0,13
Diversification of sales market (DSM)	4	1	1	1/5	1	0,14
Customer solvency (CS)	7	5	5	1	4	0,55
Marketing promotional activities (MA)	2	1	1	1/4	1	0,13

These tables carry the answers to the question "Which of the main indicators of the portfolio of orders and sales of main products has higher potential of influence?"

The following matrices (Tab. 3, 4) characterize the relative probability of occurring one of the risk gradations on the condition that the portfolio of orders and sales of main products are affected by each of the factor-indicators separately.

Table 3. The matrix of relative probability of risk occurrence for "Portfolio of orders" indicator

MS	AR	Cr.R	CR	Priorities
AR	1	3	5	0,65
Cr.R	1/3	1	2	0,23
CR	1/5	1/2	1	0,12
CI	AR	Cr.R	CR	Priorities
AR	1	1/3	1/3	0,14
Cr.R	3	1	2	0,53
CR	3	1/2	1	0,33
CI	AR	Cr.R	CR	Priorities
AR	1	2	4	0,56
Cr.R	1/2	1	3	0,32
CR	1/4	1/3	1	0,12
ILP	AR	Cr.R	CR	Priorities
AR	1	2	3	0,53
Cr.R	1/2	1	3	0,14
CR	1/3	1/3	1	0,33
SP	AR	Cr.R	CR	Priorities
AR	1	5	7	0,71
Cr.R	1/5	1	5	0,22
CR	1/7	1/5	1	0,07

Table 4. The matrix of relative probability of risk occurrence for "Sales of main products" indicator

SV	ДР	Cr.R	CR	Priorities
AR	1	4	5	0,67
Cr.R	1/4	1	3	0,22
CR	1/5	1/3	1	0,11
SM	AR	Cr.R	CR	Priorities
AR	1	5	7	0,72
Cr.R	1/5	1	4	0,20
CR	1/7	1/4	1	0,08
DSM	AR	Cr.R	CR	Priorities
AR	1	1/3	1/5	0,11
Cr.R	3	1	2	0,51
CR	5	1/2	1	0,38
CS	AR	Cr.R	CR	Priorities
AR	1	1/5	1/7	0,08
Cr.R	5	1	1	0,43
CR	7	1	1	0,49
MA	AR	Cr.R	CR	Priorities
AR	1	1/3	1/7	0,1
Cr.R	3	1	4	0,59
CR	7	1/4	1	0,31

The next stage of the pair comparison clears up the question of which of the main factors: the portfolio of orders (PO) or sale of the main product (SP) will dominate concerning one of the risk gradation (the admissible risk (AR), a critical risk (Cr.R) the catastrophic risk (CR)). The results of this comparison are presented in Table 5.

Table 5. The pair comparison of the main factors concerning the risk graduations.

AR	PO	SP	Priorities	Cr.R	PO	SP	Priorities	CR	PO	SP	Priorities
PO	1	1/3	0,247	PO	1	1/5	0,167	PO	1	1	0,5
SP	3	1	0,572	SP	5	1	0,833	SP	1	1	0,5

Further, the obtained priority vectors (Tab. 1-5) are used to construct W supermatrix, the initial form of which is shown in Table 6. The supermatrix is stochastic because the sum of all columns is unity. Therefore, the further analysis is carried out by raising it to limiting degrees that makes it possible to obtain the limiting form of Wlim. supermatrix (Table 7). Herewith all the interactions between the elements are revealed and the limiting result is obtained as which in our example is that profit mainly influence on the sales of the main products. In turn, this value is more dependent on the customer solvency.

Tables 3 and 4 show the weights of priorities ω of each risk contributing factors which are renamed as follows:

MC (Market capacity) – x_1
CI (Competitive intensity) – x_2
ILP (Innovative level of products) – x_3
SP (Readiness degree of developments for serial production) – x_4
In (Investments in R&D, technology, equipment) – x_5
SV (Sales volume) – x_6
SM (Present sales market) – x_7
DSM (Diversification of sales market) – x_8
CS (Customer solvency) – x_9
MA (Marketing promotional activities) – x_{10}
AR (Admissible risk) – R_3
Cr.R (Critical risk) - R_1
CR (Catastrophic risk) – R_2

The extracted values of the priorities from the tables 3, 4 are:

$R_1: (x_1 = 0{,}65; x_2 = 0{,}14; x_3 = 0{,}56; x_4 = 0{,}65; x_5 = 0{,}71; x_6 = 0{,}67; x_7 = 0{,}72; x_8 = 0{,}1; x_9 = 0{,}08; x_{10} = 0{,}1;);$

$R_2: (x_1 = 0{,}23; x_2 = 0{,}53; x_3 = 0{,}32; x_4 = 0{,}14; x_5 = 0{,}22; x_6 = 0{,}22; x_7 = 0{,}2; x_8 = 0{,}51; x_9 = 0{,}43; x_{10} = 0{,}59;);$

$R_3: (x_1 = 0{,}12; x_2 = 0{,}53; x_3 = 0{,}12; x_4 = 0{,}44; x_5 = 0{,}07; x_6 = 0{,}11; x_7 = 0{,}08; x_8 = 0{,}38; x_9 = 0{,}49; x_{10} = 0{,}31;);$

It allows to get the following rankings:

$R_1: x_7^{(1)} > x_5^{(2)} > x_6^{(3)} > x_1^{(4)} > x_3^{(5)} > x_4^{(6)} > x_2^{(7)} > x_8^{(8)} > x_{10}^{(9)} > x_9^{(10)};$

$R_2: x_{10}^{(1)} > x_2^{(2)} > x_8^{(3)} > x_9^{(4)} > x_3^{(5)} > x_1^{(6)} > x_5^{(7)} > x_6^{(8)} > x_7^{(9)} > x_4^{(10)};$

$R_3: x_9^{(1)} > x_8^{(2)} > x_2^{(3)} > x_4^{(4)} > x_{10}^{(5)} > x_1^{(6)} > x_3^{(7)} > x_6^{(8)} > x_7^{(9)} > x_5^{(10)};$

Then let us to make ranking the risk gradations R with respect to each priority x and to calculate the appropriate rank sums S characterizing the overall contribution of each of the risk gradations. We get the following:

$$x_1: \begin{pmatrix} R_1^{(4)} \\ R_2^{(6)} \\ R_3^{(6)} \end{pmatrix} \Rightarrow S_1 = 16; \; x_2: \begin{pmatrix} R_1^{(7)} \\ R_2^{(2)} \\ R_3^{(2)} \end{pmatrix} \Rightarrow S_2 = 11;$$

$$x_3: \begin{pmatrix} R_1^{(5)} \\ R_2^{(5)} \\ R_3^{(7)} \end{pmatrix} \Rightarrow S_3 = 17; \; x_4: \begin{pmatrix} R_1^{(6)} \\ R_2^{(10)} \\ R_3^{(4)} \end{pmatrix} \Rightarrow S_4 = 16;$$

$$x_5: \begin{pmatrix} R_1^{(2)} \\ R_2^{(7)} \\ R_3^{(10)} \end{pmatrix} \Rightarrow S_5 = 19; \; x_6: \begin{pmatrix} R_1^{(3)} \\ R_2^{(8)} \\ R_3^{(8)} \end{pmatrix} \Rightarrow S_6 = 19;$$

$$x_7: \begin{pmatrix} R_1^{(1)} \\ R_2^{(9)} \\ R_3^{(9)} \end{pmatrix} \Rightarrow S_7 = 19; \; x_8: \begin{pmatrix} R_1^{(8)} \\ R_2^{(3)} \\ R_3^{(2)} \end{pmatrix} \Rightarrow S_8 = 13;$$

$$x_9: \begin{pmatrix} R_1^{(10)} \\ R_2^{(4)} \\ R_3^{(1)} \end{pmatrix} \Rightarrow S_9 = 15; \; x_{10}: \begin{pmatrix} R_1^{(9)} \\ R_2^{(1)} \\ R_3^{(5)} \end{pmatrix} \Rightarrow S_{10} = 15.$$

Taking this into account we can write the factors ranking characterizing the degree of its risk exposure:

$$x_2 > x_8 > (x_9 \backsim x_{10}) > (x_1 \backsim x_4) > x_3 > (x_5 \backsim x_6 \backsim x_7) \quad (4)$$

From (4) it follows that the most liable to risk is x_2 factor that is the competitive intensity.

Table 6. The initial form of W supermatrix.

	PO	SP	MC	CI	ILP	SP	In	SV	SM	DSM	CS	MA	AR	Cr.R	CR
Portfolio of orders (PO)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,247	0,167	0,5
Sales of main products (SP)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,752	0,833	0,5
Market capacity (MC)	0,11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Competitive intensity (CI)	0,13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Innivative level of products (ILP)	0,12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Readiness degree for serial production (SP)	0,18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Investments in R&D, technology, equipment (In)	0,46	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sales volume (SV)	0,0	0,05	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Present sales market (SM)	0,0	0,13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Diversification of sales market (DSM)	0,0	0,14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Customer solvency (CS)	0,0	0,55	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Marketing promotional activities (MA)	0,0	0,13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Admissible risk (AR)	0,0	0,0	0,65	0,14	0,56	0,53	0,71	0,67	0,72	0,11	0,08	0,1	0,0	0,0	0,0
Critical risk (Cr.R)	0,0	0,0	0,23	0,53	0,32	0,14	0,22	0,22	0,20	0,51	0,43	0,59	0,0	0,0	0,0
Catastrophic risk (CR)	0,0	0,0	0,12	0,33	0,12	0,33	0,07	0,11	0,08	0,38	0,49	0,31	0,0	0,0	0,0

Table 7. The limiting form of W supermatrix (the matrix form is the same as in the Tab. 6)

0,2967182	0,2967183	0	0	0	0	0	0	0	0	0	0	0	0	0
0,7032818	0,7032817	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0,0326390	0,0326390	0,0326390	0,0326390	0,0326390	0,0326390	0,0326390	0,0326390	0,0326390	0,0326390	0	0	0
0	0	0,0385734	0,0385734	0,0385734	0,0385734	0,0385734	0,0385734	0,0385734	0,0385734	0,0385734	0,0385734	0	0	0
0	0	0,0356062	0,0356062	0,0356062	0,0356062	0,0356062	0,0356062	0,0356062	0,0356062	0,0356062	0,0356062	0	0	0
0	0	0,0534093	0,0534093	0,0534093	0,0534093	0,0534093	0,0534093	0,0534093	0,0534093	0,0534093	0,0534093	0	0	0
0	0	0,1364904	0,1364904	0,1364904	0,1364904	0,1364903	0,1364904	0,1364904	0,1364904	0,1364905	0,1364904	0	0	0
0	0	0,0351641	0,0351641	0,0351641	0,0351641	0,0351641	0,0351641	0,0351641	0,0351641	0,0351641	0,0351641	0	0	0
0	0	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0	0	0
0	0	0,0984595	0,0984594	0,0984595	0,0984594	0,0984595	0,0984595	0,0984595	0,0984594	0,0984594	0,0984594	0	0	0
0	0	0,3868050	0,3868050	0,3868050	0,3868049	0,3868050	0,3868050	0,3868050	0,3868049	0,3868049	0,3868050	0	0	0
0	0	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0,0914266	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0,3120749	0,3120748	0,3120752
0	0	0	0	0	0	0	0	0	0	0	0	0,3733536	0,3733537	0,3733535
0	0	0	0	0	0	0	0	0	0	0	0	0,3145715	0,3145716	0,3145713

Conclusions

The paper proposes one of the possible procedures of qualitative sinmulation and subsequent analysis of a complex of factors, which may be the source of risk situations in the activity of enterprises and industries involved in innovative activities. This technology allows to compose recommendations that represent a variety of solutions for the decision maker (DM).

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ЯКІСНЕ МОДЕЛЮВАННЯ РИЗИКОУТВОРЮЮЧИХ ФАКТОРІВ НАУКОМІСТКИХ ПІДПРИЄМСТВ І ВИРОБНИЦТВ

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Розглянуто планування діяльності наукомісткого підприємства в умовах невизначеності економічної ситуації і тих, що виникають в процесі ризиків, пов'язаних з інноваціями у виробництві. Застосована методика якісного моделювання на основі суб'єктивних (експертних) оцінок і багаторівневих аналітичних мереж з градаціями можливих ризиків. Для аналізу сукупності факторів, які можуть бути джерелом виникнення ризикових ситуацій в процесі діяльності підприємств та виробництв, що займаються інноваційною діяльністю, використана технологія якісного моделювання, яка дозволяє формувати рекомендації, що представляють собою різні варіанти рішень, для особи, яка приймає рішення.

Ключові слова: ризикоутворюючі фактори, якісне моделювання, аналітичні мережі, рівні ієрархії, матриця, попарне порівняння.

КАЧЕСТВЕННОЕ МОДЕЛИРОВНАИЕ ФАКТОРОВ НАУКОЕМКИХ ПРЕДПРИЯТИЙ И ПРОИЗВОДСТВ

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Рассмотрено планирование деятельности наукоемкого предприятия в условиях неопределенности экономической ситуации и возникающих в процессе рисков, связанных с инновациями в производстве. Применена методика качественного моделирования на основе субъективных (экспертных) оценок и многоуровневых аналитических сетей с градациями возможных рисков. Для анализа совокупности факторов, которые могут быть источником возникновения рисковых ситуаций в процессе деятельности предприятий и производств, занимающихся инновационной деятельностью использована технология качественного моделирования, которая позволяет формировать рекомендации, представляющие собой различные варианты решений, для лица, принимающего решения.

Ключевые слова: *рискообразующие факторы, качественное моделирование, аналитические сети, уровни иерархии, матрица, попарное сравнение.*