Data structures, logical-probabilistic models and digital management of the safety and quality of systems in the economics

Eugene Solozhentsev*

Institute of Business Technologies,
Department of Information Technologies in Business,
Saint-Petersburg State University of Aerospace Instrumentation,
Saint-Petersburg, ul. Bolshaya Morskaya, 67, 190000, Russia
and
Laboratory of Intelligent Integrated Systems of
Computer-Aided Design,
Institute of Problems on Mechanical Engineering,
Russian Academy of Sciences,
Bolshoi 61, V.O., Saint-Petersburg, 199178, Russia
Fax: +7-(812)-321-47-71
Email: esokar@gmail.com
*Corresponding author

Ekaterina Karaseva

Institute of Business Technologies,
Department of Information Technologies in Business,
Saint-Petersburg State University of Aerospace Instrumentation,
Saint-Petersburg, ul. Bolshaya Morskaya, 67, 190000, Russia
Email: matatkakate@gmail.com

Abstract: In this paper we are considering data structures in economic systems. These structures can be used to construct logical-probabilistic risk models intended for digital management of safety and quality of systems. Transformation of any database into a system of logical equations is described, which is the basis for constructing logical-probabilistic models of safety or quality. We give examples how the database is used to construct models of the credit risk in banks and the risk and efficiency of restaurants. Also we present examples of using complex structure data to construct a model for management of a country's innovation system quality and simple structure data for construction of a model for assessment of the failure risk for one innovation. The special software 'Arbiter' and 'Expa' for management in economics are described. The term 'digital management' is defined and computer network components for digital management of systems in economics are given.

Keywords: data structure; social and economic systems; logical-probabilistic risk models; safety; quality; efficiency.

Reference to this paper should be made as follows: Solozhentsev, E. and Karaseva, E. (2020) 'Data structures, logical-probabilistic models and digital management of the safety and quality of systems in the economics', *Int. J. Risk Assessment and Management*, Vol. 23, No. 1, pp.27–53.

Biographical notes: Eugene Solozhentsev is a Professor in the Department of Information Technologies in Business at St. Petersburg State University of Aerospace Instrumentation (SUAI), Russia, and Head of the Laboratory of Intelligent Integrated Automated Systems of Design of the Institute of Problems of Mechanical Engineering (IPME) of Russian Academy of Sciences, Russia. He is also an Honoured Scientist of the Russian Federation, and the Chairman of the International Program and National Organizing Committees of the 'Modelling and Risk and Safety Analysis in Complex Systems' International Science Schools, Russia. He has published more than 300 scientific works, including nine books.

Ekaterina Karaseva is an Associate Professor in the Department of Information Technologies in Business, Saint-Petersburg State University of Aerospace Instrumentation. She received her degree in Qualification-Economist from Belorussian State University of Economics, Faculty of Banking and Finance in 2007. She is a candidate of Economic Science with the dissertation entitled 'Estimation and regulation of operational risk in bank'. Her research interests include operational risk, financial risk, banking and modelling.

1 Introduction

Numerous datasets are used to make decisions in economics. The effectiveness of solutions depends essentially on mathematical models which are constructed on datasets. This work is devoted to the problem of how to increase the efficiency of using data in economics on the basis of constructing logical-probabilistic (LP) models of safety and quality and digital technology for management of socio-economic systems. The solution of the problem is considered in the following examples:

1. database (DB) and construction of LP model of bank's credit risk
2. database and construction of the LP-model of restaurant's risk and efficiency
3. complex structure data and construction of LP model for management of the country's innovation system quality
4. simple structure data and construction of the LP model for assessment of the failure risk for one innovation.

Examples of a complex structure data are data of systems: counteraction to narcotisation in the country and the region, management of innovations in the country, estimation of education quality in universities, the effectiveness of management in socio-economic system and the ministry, etc. Examples of a simple structure data are data for special tasks, for example, indicative hazard system indicators, etc.

At present, there are no adequate mathematical models for analysis and management of safety and quality in economics, so the problem of using data for management of safety and quality on the basis of mathematical models is actual.

The scientific and practical significance of this work is of construction the LP models for digital management of safety and quality in economics on different data structures.

The aim of the work is methods which allow to use data with different structures for construction of LP models of safety and quality of economic systems and to give relevant examples.

1.1 Objectives

- Outline the technique for transformation of any database into a system of logical equations.
- Outline the technique for construction the of LP model of the credit risk in banks using DB of credits.
- Outline the technique for construction of the LP model of efficiency and risk using DB of the daily turnover in restaurants.
- Outline the technique for construction of the LP model of the country's innovation system quality on the complex structure data, describing the states of the system.
- Outline the technique for construction of the LP model of the failure risk for one innovation on the simple structure data, describing the process of development of previous innovations.
- Describe special software for construction and analysis of LP models of safety and quality.
- Define the term 'digital management' in the economics and the components of a network for digital management of safety and quality on data having different structures.

2 Transformation of a database into a knowledge base

Tabular database (Table 1) contains statistical information about homogeneous objects or states of the system. In the table, the number of columns can reach several tens, and the rows – hundreds. The values of indicators (parameters) can be quantitative or qualitative, discrete or continuous (Solozhentsev, 2016).

Table 1 Database states of the system and values of indicators

State	*Indicator,* A_1	…	*Indicator,* A_j	…	*Indicator,* A_n	*Efficiency parameter,* E_i
1	A_{11}	…	A_{1j}	…	A_{1n}	E_1
…	…	…	…	…	…	…
I	A_{i1}	…	A_{ij}	…	A_{in}	E_i
…	…	…	…	…		
N	A_{N1}	…	A_{Nj}	…	A_{Nn}	E_N

A structural representation of the data is used in the tabular DB of the system. The DB includes: a set of states or objects; continuous or discrete parameters which describe states or objects.

In the problems of risk, we use following notations for random events and corresponding logical variables:

- $Z_1, \ldots, Z_j, \ldots, Z_n$ are events-indicators; Z_{jr} – events-grades, $j = 1, 2, \ldots, n$; $r = 1, 2, \ldots, N_j$
- Y is the object or state efficiency parameter
- Y_r, $r = 1, 2, \ldots, N_y$ – events-grades of the efficiency parameter.

In a risk scenario, events-indicators are connected by the logical connections OR, AND, NOT. Events-grades for each indicator form a group of inconsistent events (GIE). The greatest number of different states of the system (different objects) is equal to:

$$N_{\max} = N_1 \cdot N_2 \cdot \ldots \cdot N_j \cdot \ldots \cdot N_n, \tag{1}$$

where $N_1, \ldots, N_j, \ldots, N_n$ are the grade numbers in the exponents.

DB indicators can be continuous and equal to sets of values. Values of state indicators are presented in the cells of Table 1. Quantitative and qualitative scales are used for their measurement. The last column of the table is the efficiency parameter. We denote indicators as $A_1, \ldots, A_j, \ldots, A_n$ and the efficiency parameter as E_i, $i = 1, \ldots, N$.

2.1 Events-indicators and events-grades

Let change the DB representation by replacing the values of indicators with their grades and call them variables. The efficiency parameter E takes values from the set $\{E_1, \ldots, E_r, \ldots, E_m\}$. The parameter E depends on $A_1, \ldots, A_j, \ldots, A_n$. The variable A_j takes values (grades) from the set $\{A_{j1}, \ldots, A_{jr}, \ldots, A_{j\,Nj}\}$.

Statistical data is represented by a table where i^{th} row has the form

$$A_{r1}^i, \ldots, A_{r2}^i, \ldots, A_{rn}^i, E_r^i,$$

where

$$i \in \{1, 2, \ldots, N\}; \; r \in \{1, 2, \ldots, N_i\};$$
$$r_1 \in \{1, 2, \ldots, N_1\}; \; r_2 \in \{1, 2, \ldots, N_2\};$$
$$r_j \in \{1, 2, \ldots, N_j\}; \; r_n \in \{1, 2, \ldots, N_n\}.$$

Table 2 States, events and logical variables

State	*Indicator, A_1*	…	*Indicator, A_j*	…	*Indicator, A_n*	*Efficiency parameter, E_i*
1	Z_{1r1}^1		Z_{jrj}^1		Z_{nrn}^1	Y_{ry}^1
…	…		…		…	…
I	Z_{1r1}^i		Z_{jrj}^i		Z_{nrn}^i	Y_{ry}^i
…	…		…			
N	Z_{1r1}^N		Z_{jrj}^N		Z_{nrn}^N	Y_{ry}^N

We introduce random events (Table 2). The event Z_{jr} is in the fact that the variable A_j takes the value $A_{jr} \equiv Z_{jr}$ for any i-string; $A_j = A_{jr}$. The probability of this events: $P(Z_{jr}) = P(A_j = A_{jr})$. The Y_r event is that the variable E takes the value E_r: $Y_r\, E = E_r$ for any i-string.

The probability of the event: $P(Y_r) = P(E = E_r)$. We assign logical variables with the same identifiers to events Z_{jr}, $j = 1, \ldots, n$; $r = 1, \ldots, N_j$ and Y_r, $r = 1, \ldots, N_y$. Let introduce events $Z_1, \ldots, Z_j, \ldots, Z_n$ and Y, each of them includes GIE: $Z_j = Z_{j1}, \ldots, Z_{jr}, \ldots, Z_{jNj}$, $j = 1, 2, \ldots n$; $Y = Y_1, \ldots, Y_r, \ldots, Y_{ny}$.

Further, we will consider this table as a tabular knowledge base (KB).

2.2 The failure of states

Logical function of the failure risk for the state Y is:

$$Y = Z_1 \vee Z_2 \vee \ldots \vee Z_j \vee \ldots Z_n, \tag{2}$$

where $Z_1, Z_2, \ldots, Z_n$ are logical variables of state indicators. The logical function Y means the failure event and assign to indicators $Z_1, \ldots, Z_n$ the sense: influence on the failure event Y.

Logical function of the state's failure in the orthogonal form:

$$Y = Z_1 \vee Z_2 \overline{Z_1} \vee Z_3 \overline{Z_2}\,\overline{Z_1} \vee \ldots \tag{3}$$

Orthogonality means: the multiplication of any two logical components in (3) is equal to zero. This allows us make transition from logics to arithmetic and write probabilistic function of failure:

$$P(Y=0) = P_1 + P_2(1-P_1) + R_3(1-P_2)(1-P_1) + \ldots, \tag{4}$$

where $P_j = P\{Z_j\}$ is the probability of fact that independent events Z_j lead to the failure Y.

For every state in formula (4), we can place probability of failure of the corresponding event-grade from the GIE for this parameter (event) instead of the probability of event Z_j. The probabilities of events-grades are determined by the identification method according to statistical data in DB with use of Bayes' formula (Solozhentsev, 2016; Karasev, 2015).

Accordingly to (2), the system of logical equations from the statistical data (Table 2) for the failure of the states of the system is written as follows:

$$\begin{cases} Z^1{}_{1r1} \vee \ldots \vee Z^1{}_{jri} \vee \ldots \vee Z^1_{nrn} = Y^1_{ry}; \\ \ldots\ \ldots\ \ldots\ \ldots \\ Z^i{}_{1r1} \vee \ldots \vee Z^i{}_{jri} \vee \ldots \vee Z^i_{nrn} = Y^i_{ry}; \\ \ldots\ \ldots\ \ldots\ \ldots \\ Z^N{}_{1r1} \vee \ldots \vee Z^N{}_{jri} \vee \ldots \vee Z^N_{nrn} = Y^N_{ry}. \end{cases} \tag{5}$$

For (5), taking (4) into account, we write the system of probabilistic equations for the failure of the system's states:

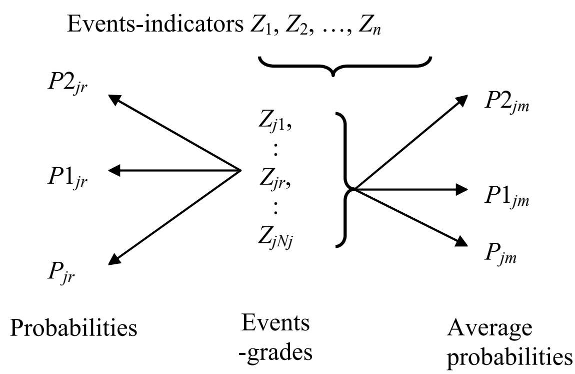
$$\begin{cases} P^1{}_{1r1} + P^1{}_{2r2}\left(1-P^1_{1r1}\right) + P^1{}_{3r3}\left(1-P^1_{1r1}\right)\left(1-P^1_{2r2}\right) + \ldots = P\left(Y^1 = 0\right); \\ \ldots\ \ldots\ \ldots\ \ldots \\ P^i{}_{1r1} + P^i{}_{2r2}\left(1-P^1_{1r1}\right) + P^i{}_{3r3}\left(1-P^1_{1r1}\right)\left(1-P^1_{2r2}\right) + \ldots = P\left(Y^i = 0\right); \\ \ldots\ \ldots\ \ldots\ \ldots \\ P^N{}_{1r1} + P^N{}_{2r2}\left(1-P^1_{1r1}\right) + P^N{}_{3r3}\left(1-P^1_{1r1}\right)\left(1-P^1_{2r2}\right) + \ldots = P\left(Y^N = 0\right). \end{cases} \tag{6}$$

2.3 Groups of incompatible events

For event-grade $Z_{j\kappa}$ of the parameter Z_j three probabilities are used (Figure 1). For logics in GIE, logical identities for events-grades are correct:

$$\begin{aligned} &z_{jr} \wedge z_{jk} = 0; \\ &\overline{z_{jr}} \vee \overline{z_{jk}} = 1; \\ &\overline{z_{jr}} \wedge z_{jk} = z_{jk}; \\ &z_{jr} \vee \overline{z_{jk}} = \overline{z_{jk}}. \end{aligned} \tag{7}$$

Figure 1 Probabilities in GIE



Following rules for the replacement of events-grades by their probabilities are valid:

$$\begin{cases} P\left(z_{jr} \wedge z_{jk}\right) = 0; \\ P\left(\overline{z_{jr}} \vee \overline{z_{jk}}\right) = 1; \\ P\left(z_{jr} \vee z_{jk}\right) = P\left(z_{jr}\right) + P\left(z_{jk}\right) = P2_{jr} + P2_{jk}; \\ P\left(\overline{z_{jr}} \wedge \overline{z_{jk}}\right) = 1 - \left(P\left(z_{jr}\right) + P\left(z_{jk}\right)\right) = 1 - \left(P2_{jr} + P2_{jk}\right). \end{cases} \tag{8}$$

2.4 Logics and probabilities in the GIE for failure of states

For each GIE, the following three probabilities of the events-grades Z_{jr} are considered: $P2_{jr}$ is the frequency of a state in statistical data; $P1_{jr}$ is the probability in the GIE; P_{jr} is the probability of event-grade Z_{jr} leads to the risk of the system Y. Probabilities for the GIE are defined as follows (Solozhentsev, 2016):

$$\begin{aligned} &P2_{jr} = P\left(z_{jr}\right); \qquad \sum P2_{jr} = 1, r = 1, 2, \ldots, N_j; \\ &P_{jr} = P\left(z_{jr}\right)\Big|_{Y=0}, \qquad r = 1, 2, \ldots, N_j; \\ &P1_{jr} = P_{jr} \Big/ \sum P_{jr}; \quad \sum P1_{jr} = 1, r = 1, 2, \ldots, N_j. \end{aligned} \tag{9}$$

Average probabilities $P2_{jr}$, $P1_{jr}$ and P_{jr} for grades in GIE are equal to:

$$\begin{cases} P2_{jm} = 1/N_j\,; \\ P_{jm} = \sum_{r=1}^{N_j} P_{jr} P2_{jr}\,; \\ P1_{jm} = \sum_{r=1}^{N_j} P1_{jr} P2_{jr}. \end{cases} \tag{10}$$

In the logical risk function of i-state of the system we have to place logical variables Z_{jr}, $j = 1, 2, \ldots n$, $r = 1,2, \ldots, N_j$ for the events-grades (which correspond to state *i*), instead of the logical variables $Z_1, \ldots, Z_j, \ldots, Z_n$,. The probability of the event-parameter Z_j is equal to the probability of one of the events Z_{jr} from the GIE, that is, $P(Z_{jr} \mid {}_{Y=0}) = P_{jr}$.

2.5 Bayes' formula for GIE

Probabilities P_{jr} are estimated by algorithmic iterative learning of the probabilistic model under statistical data. Primarily we need to determine probabilities $P1_{jr}$ satisfying (10), and then make transition from $P1_{jr}$ to the probabilities P_{jr}. The number of independent probabilities P_{jr} is

$$N_{ind} = \left(\sum_{j=1}^{n} N_j \right) - n. \tag{11}$$

Probabilities P_{jr}, $P1_{jr}$, $P2_{jr}$, P_{jm}, $P1_{jm}$ and $P2_{jm}$ are related by the Bayes' formula. This connection is used in learning LP-model by statistical data. We are solving the problem of identification (optimisation) by iterative method. The Bayes' formula can formally be written with respect to $P1_{jr}$ as function P_{jr} or, conversely, with respect to P_{jr} as function $P1_{jr}$. For the iterative learning of the probabilistic model, the Bayes' formula can be written as follows:

$$P_{jr} = P1 \frac{P_{jm}}{P2_{jr}}, \quad r = 1, 2, \ldots, N_j,\ j = 1, 2, \ldots, n. \tag{12}$$

This allows generate a number of independent probabilities $P1_{jr}$ in the GIE one less than in case where we generate probabilities P_{jr}. The estimation of the accuracy of probabilities $P1_{jr}$ in the GIE is also simplifier because their sum is equal to 1.

There are difficulties in application the Bayes' formula, since the denominator in (12) can be equal to zero or very small due to limited amount of statistical data. Therefore, the connection between probabilities P_{jr} and $P1_{jr}$ is suggested to be specified by modifying the Bayes' formula using the mean value of probability $P2_{jr}$ (Solozhentsev, 2016):

$$P_{jr} = P1 \frac{P_{jm}}{P2_{jm}}, \quad r = 1, 2, \ldots, N_j,\ j = 1, 2, \ldots, n. \tag{13}$$

3 DB and LP model for credit risk management in banks

Individual loans are described by 20 parameters (Table 3), each of them has from 2 to 11 grades (Solozhentsev, 2016; Karasev, 2015). Credit parameters and their grades are considered as random events-parameters Z_i and events-grades Z_{jr}. The events-grades of every parameter form GIE. Scenario risk of credit's default is: default occurs if any one, or any two, or … all events-parameters will take place.

Table 3 Description of credit parameters (for individuals)

Parameters	*Title of parameter*	*Notation*	*Number of grades*
0	Parameter of default	Y	2
1	Status of existing checking account	Z_1	4
2	Duration in month	Z_2	10
3	Credit history	Z_3	5
4	Purpose	Z_4	11
5	Credit amount	Z_5	10
6	Savings account/bonds	Z_6	5
7	Present employment since	Z_7	5
8	Instalment rate in percentage of disposable income	Z_8	4
9	Personal status and sex	Z_9	4
10	Other debtors/guarantors	Z_{10}	3
11	Present residence since	Z_{11}	4
12	Property	Z_{12}	4
13	Age in years	Z_{13}	5
14	Other instalment plans	Z_{14}	3
15	Housing	Z_{15}	3
16	Number of existing credits at this bank	Z_{16}	4
17	Job	Z_{17}	4
18	Number of people being liable to provide maintenance for	Z_{18}	2
19	Telephone	Z_{19}	2
20	Foreign worker	Z_{20}	2

Logical model of credit default risk:

$$Y = Z_1 \vee Z_2 \vee \ldots \vee Z_n.$$

Logical model of credit default risk in equivalent orthogonal form:

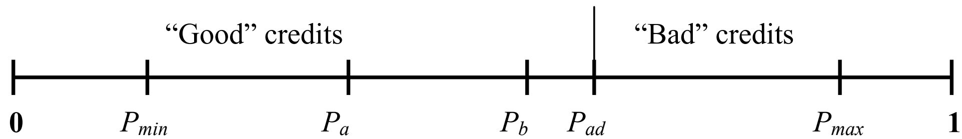
$$Y = Z_1 \vee Z_2 \overline{Z_1} \vee Z_3 \overline{Z_2}\,\overline{Z_1} \vee \ldots$$

Probabilistic model of credit default risk:

$$P = P_1 + P_2 Q_1 + P_3 Q_1 Q_2 + \ldots \tag{14}$$

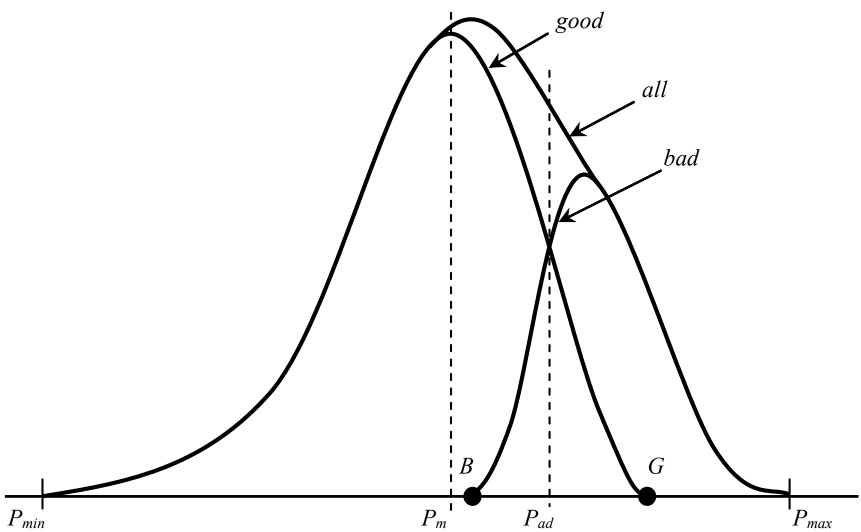
where P_1, P_2, … are probabilities of credit default due to parameters; $Q_1 = 1 - P_1$, $Q_2 = 1 - P_2$, … In the formula (14) probabilities for events-grades Z_{jr} are placed. Credit risk (probability of default) is within the interval [0, 1] for any values of their probabilities. Risk is determined for every credit. Credits in DB are classified by risk value (Figure 2).

Figure 2 Scheme of credit classification by risk



Identification of the LP model of credit risk is based on statistical data (Solozhentsev, 2016; Karasev, 2015) and this is determination probabilities of events-grades P_{jr}, $r = 1, 2, \ldots, N_j$; $j = 1,2 \ldots, n$, admissible credit risk P_{ad} and risks P_i, $i = 1,2, \ldots, N$ of credits. The condition $P_i > P_{ad}$ distinguishes following types of credits: N_{gg} – are 'good' by LP-model and statistics; N_{gb} – are 'good' by LP-model and 'bad' by statistics; N_{bg} – 'bad' by LP-model and 'good' by statistics; N_{bb} – 'bad' by LP-model and statistics (Figure 3).

Figure 3 Distribution of good credits, bad credits and all together



3.1 New tasks in credit risk management

The LP model of credit risk provides the solution of new tasks for credit risk management (Karasev, 2015):

1 quantitative assessment the risk for every credit and the average risk of the bank

2 estimation contributions of credit's parameters and their grades in the average credit risk

3 determination admissible risk from the condition of a given asymmetry of recognition of ‘good’ and ‘bad’ credits

4 exclusion from the statistics of the bank, which are used for credit risk model learning, obsolete and incorrect credits

5 relearning LP model of the credit risk after the forming the signal part of finalised credits.

LP models of credit risk have following advantages:

- the accuracy in risk assessment of ‘good’ and ‘bad’ credits is increased by 1.5 to 2.5 times, bank’s losses are accordingly reduced
- the robustness (stability) of classification of credits into ‘good’ and ‘bad’ is increased seven times in comparison with models, based on neural networks
- optimal management for bank crediting process is ensured
- management of quality of whole crediting process is performed by change parameters of LP model and monitoring technology.

4 DB and LP model for management of risk and efficiency in restaurants

Efficiency (turnover per day) Y is considered as a random variable, depending on the parameters of Z. The parameters are represented by sets of discrete values, which are called events-grades and denoted by logical variables.

Statistics for the calendar year (N = 365 days) were considered. The state of the restaurant is determined by following parameters and their grades:

Z_1 month, grades: 1, 2, …,12

Z_2 day, grades: 1, 2,…,7

Z_3 type of advertising:

1 for months 3,…,8

2 for months 9, …, 2

Z_4 type of team determines team structure and depends on season and day of the week:

1 for months 9, …, 12; 1, 2 in days 1, 2, 3, 4

2 for months 9, 10, 11, 12, 1, 2 in days 5, 6, 7

3 for months 3, 4, 5, 6, 7, 8 in days 1, 2, 3, 4

4 for months 3, 4, 5, 6, 7, 8 in days 5, 6, 7

Z_5 quality of personnel:

1 inexperienced (2006 – for months 11, 12)

2 average skill (2007 – for months 1, 2, 3)

3 experts (2007 – for months 4,…,10)

Z_6 type of menu:

1 2006, for months 11, 12 (70 % usual plus 30 % gourmet)

2 2007, for months 1, 2 (65 + 35 %)

3 2007, for months 3, 4 and 5 (60 + 40 %)

4 2007, for months 6, 7, 8 (55 + 45 %)

5 2007, for months 9, 10 (50 + 50 %)

Z_7 type of evening:

1 usual

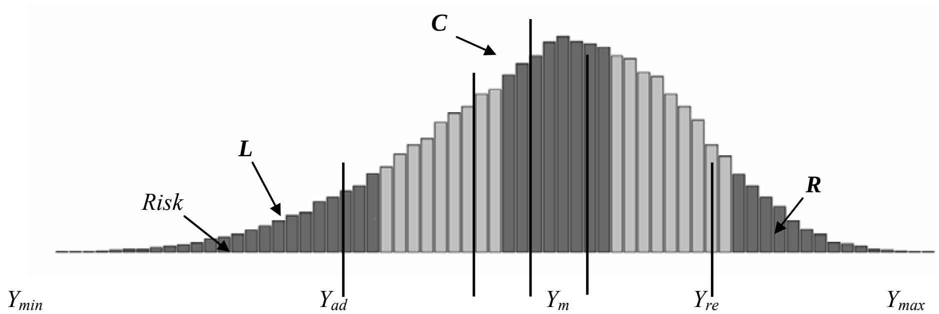
2 usual plus banquet

3 usual plus thematic

4 usual oplus tasting.

Let construct turnover Y distribution histogram entering intervals on 25,000.0 RUR. We have obtained 23 intervals or events-grades for the efficiency parameter and the number of days, where turnover was included in the interval, was calculated (Figure 4).

Figure 4 Distribution histogram for efficiency parameter



Monitoring of the restaurant's states was performed during the calendar year (N = 365 days) and in each interval there are, in average, N/N_y = 365/23 = 16 restaurant's states.

The identification (learning) of LP models of restaurant's risk is based on statistical data (Solozhentsev, 2016; Karasev, 2015) and this is determination probabilities of events-grades of parameters P_{jr}, $r = 1, 2, \ldots, N_j$; $j = 1, 2 \ldots, n$ and admissible turnover.

4.1 New tasks in analysis of risk and efficiency of the restaurant

The transition from DB to KB and construction of the LP model of risk and efficiency provide the opportunity to manage the risk and efficiency of the restaurant ((Solozhentsev, 2016).

The restaurant's risk LP model is constructed and probabilities of grades are determined by the identification method under statistical data. Calculations have demonstrated:

- The risk by months is almost 10 times different. The most risky – the first months of the restaurant's functioning (11, 12, 1, 2, 3, 4).
- The risk by days differs also almost 10 times. Less risky are Friday and Saturday (Grades 5, 6).
- The risk from both types of advertising (1, 2) is almost the same.
- The risk from types of teams differs almost twice (1, 4).
- The risk from the quality of personnel (1, 2, 3) is almost the same.
- The risk from the menu type is almost 25 times different (3, 5). The least risky is the menu of type 5.
- The risk of evening type changes almost 400 times (1 – usual evening has the greatest risk, 2 – evening with a banquet has the least risk).

Analysis of the restaurant's risk by contributions of parameters to the 'tail' of the turnover distribution was made both for the entire distribution and in the 'tail' only (Table 4).

Table 4 Analysis of significances of parameters for restaurant's risk (Y_{ad} = 125000.0 RUR)

Parameters	P_{jm} *all*	P_{jmb} *– in the 'tail'*
1	0.06242	0.09822
2	0.06209	0.08572
3	0.06236	0.06620
4	0.06249	0.08210
5	0.07103	0.06826
6	0.05986	0.09499
7	0.06444	0.07223

The risk of efficiency Y is proportional to probabilities of influencing parameters Z. Therefore, the mean values of probabilities P_{jm} of grades of influencing parameters Z can be considered as significances of parameters for the average efficiency risk.

In Table 4 (column 2) mean values of probabilities P_{jm} of grades of parameters in the GIE for all restaurant's states (interval of variation Y) are shown. Mean values of probabilities P_{jm} of grades of parameters in the GIE for the 'tail' of the restaurant's efficiency parameter (column 3) distribution are also determined under the condition $Y < 125{,}000.0$ RUR, that is, for 'bad' states. The results allow us to draw the following conclusions:

- For the interval of variation Y, contributions of parameters in the average risk P_{jm} are the same.
- Contributions of parameters in the average risk depend on the size of the 'tail'. Contributions of parameters differ almost twice. For the 'tail' Y < 125,000.0 RUR – the largest contribution has parameter 1 (months) and the smallest – parameter 3 (advertising). For the tail $Y < 75{,}000.0$ RUR the largest contribution has parameter 1 (months) and the smallest – parameter 7 (type of evening).

- The difference in contributions of parameters to the risk increases with the decreasing of the admissible value of the efficiency parameter.

Thus, we demonstrate possibility to manage the restaurant's risk and efficiency by change the type and quality of advertising, type of menu, type of the evening (usual, usual plus banquet, usual plus thematic, usual plus tasting) and improving the qualification of the staff.

Technology for management of risk and efficiency in restaurant business can be extended to public catering facilities, shops, warehouses and enterprises.

The BD contains description of restaurant's daily states, including values of parameters Z_1, Z_2, …, Z_n and turnover Y. Based on the nature of parameters Z and their grades, it is impossible to construct analytical model (function) for the turnover of Y from Z. In order to analyse and manage the turnover, we have to know contributions of events-grades of parameters to the value of turnover. To do this we need to construct the model for the efficiency and risk of the restaurant's turnover.

The algorithm of the transition from DB to KB for risk management of the restaurant includes:

1 construct turnover distribution histogram

2 choose the minimum admissible turnover $Y_{\min}$

3 declare states with turnover $Y < Y_{\min}$ as 'bad' and denote them 0, and states with turnover $Y > Y_{\min}$ we declare as 'good' and denote them 1

4 calculate the risk of turnover: Risk = N_{bat} / N_{all}, where N_{bat} – the number of bad states; N_{all} – the number of all restaurant states in the DB

5 write the logical function of risk for each state of turnover (1, 3)

6 write the probabilistic function of risk for each state of turnover (2, 4)

7 calculate probabilities of events-grades, solving the system of equations (4) by the nonlinear identification method (Solozhentsev, 2016; Karasev, 2015)

8 these estimations of probabilities of events-grades allow us to calculate their contribution to the risk and efficiency of the restaurant's turnover

9 manage the risk and effectiveness of the restaurant, based on the obtained estimations.

5 Complex structure data. Construction of LP model for management of country's innovation system quality

The innovation system is most important for the State because provides increasing of profits from industry and business. Russia's innovation system is ranked 62nd among 142 countries and the country's rating has to be raised (Solozhentsev, 2016).

Resources are needed to manage the state and development of the country's economics. Innovation management system is needed to reduce the loss of funds and increase their revenues. The rule of Chinese leadership (Li Keqiang) was accepted which declare both innovations in technology and innovations in management are equal. We propose to use an event approach to manage the innovation system with a mathematical correct logical addition of events (Solozhentsev, 2016; Ryabinin, 2007).

5.1 Complex structure data and assessment of the global innovation index of the country

Let consider the technique for assessment Global Innovative Index (GII) for a country and estimation the innovation system quality, which was adopted in international practice (Solozhentsev, 2016). The GII is calculated based on values of the Innovative Index of Production (IIP) and the Innovative Index of Results (IIR), every index is determined by values of groups of indicators (Table 5):

- seven groups of derivative indicators of the first level $Y_1, Y_2, \ldots, Y_7$
- 21 groups of derivative indicators of the second level $Y_{11}, Y_{12}, Y_{13}, \ldots, Y_{71}, Y_{72}, Y_{73}$
- 84 low-level initial indicators $Y_{111}, Y_{112}, Y_{11\,3}, \ldots, Y_{731}, Y_{732}, Y_{733}$.

Five groups of indicators assess capabilities of the innovation system:

1 institutions – the state (political environment, regulatory environment, business environment)

2 human capital and research (education, science and development)

3 infrastructure (information technologies, etc.)

4 market (credits, investments, trade and competition)

5 business (qualification of employees, business communication with innovation and knowledge).

Two groups of indicators evaluate the results of the innovation system:

6 results of scientific research

7 results of creative research.

The table uses following abbreviations: GNI – gross national income; PPP – purchasing power parity; FDI – foreign direct investment; IPS – international patent system; FLD – first level domain.

Each of seven first level groups has several indicators. The value of the group indicator is calculated as the arithmetic mean of individual indicators of the second level (their number is 21). Each second level indicator is a function of the initial indicators (their number is 84). Following calculations are performed:

1 the IIP is calculated as the arithmetic mean of the first five groups of indicators

2 the innovative index of results is calculated as the arithmetic mean of the last two groups of indicators

3 the final GII is calculated as the arithmetic average of the IIP and the innovative index of results

4 the innovation efficiency ratio is calculated as the ratio of the innovative index of results to the IIP.

Table 5 Data of complex structure of GII of Russian Federation

Indicators	*Identificator*	*Score*	*Rank*
Global innovative index	GII	37.2	62
Innovative index of production	IIP	30.6	72
Innovative index of results	IIR	43.8	52
Innovation Efficiency Ratio IIR/IIP	IER	0.7	104
1 Institutions	Y_1	56.0	87
1.1 Political environment	Y_{11}	42.9	117
1.1.1 Political stability and safety	Y_{111}	44.7	113
1.1.2 Government effectiveness	Y_{112}	27.3	90
1.1.3 Freedom of the press	Y_{113}	56.6	119
1.2 Regulatory environment	Y_{12}	57.2	100
1.2.1 Regulatory quality	Y_{121}	40.3	102
1.2.2 Rule of law	Y_{122}	26.2	113
1.2.3 Cost of redundancy dismissal, salary weeks	Y_{123}	17.3	82
1.3 Business environment	Y_{13}	68.0	55
1.3.1 Ease of starting a business	Y_{131}	83.6	69
1.3.2 Ease of resolving insolvency	Y_{132}	46.5	49
1.3.3 Ease of paying taxes	Y_{133}	73.9	53
2 Human capital and research	Y_2	44.1	33
2.1 Education	Y_{21}	62.0	42
2.1.1 Expenditure on education, % GDP	Y_{211}	n/a	n/a
2.1.2 Gov't expend. on edu./pupil, secondary	Y_{212}	19.7	57
2.1.3 School life expectancy, years	Y_{213}	14.3	48
2.1.4 PISA scales in reading, maths and science	Y_{214}	46.8	37
2.1.5 Pupil-teacher ratio, secondary	Y_{215}	8.5	11
2.2 Tertiary education	Y_{22}	40.0	46
2.2.1 Tertiary enrolment, % gross	Y_{221}	75.9	13
2.2.2 Graduates in science and engineering, %	Y_{222}	28.1	14
2.2.3 Tertiary inbound mobility, %a	Y_{223}	1.4	71
2.2.4 Number of persons admitted to higher education institutions abroad with higher education, %.	Y_{224}	0.4	108
2.3 Research and development (R&D)	Y_{23}	30.3	31
2.3.1 Researchers, FTE/mn pop	Y_{231}	2.58	32
2.3.2 Gross expenditure on R&D, % GDP	Y_{232}	1.1	33
2.3.3 Global R&D firms, avg. exp. top 3, mn $US	Y_{233}	45.9	25
3 Infrastructure	Y_3	37.2	49
3.1 Information and communication technologies (ICTs)	Y_{31}	59.6	28
3.1.1 ICT access	Y_{311}	66.9	34
3.1.2 ICT use	Y_{312}	39.7	34
3.1.3 Government's online service	Y_{313}	66.0	37
3.1.4 E-participation	Y_{314}	65.8	19

Table 5 Data of complex structure of GII of Russian Federation (continued)

Indicators	*Identificator*	*Score*	*Rank*
3.2 General infrastructure	Y_{32}	32.0	57
3.2.1 Electricity output, kWh/cap	Y_{321}	7.30	28
3.2.2 Power Consumption kWh/cap	Y_{322}	6.46	27
3.2.3 Logistics performance	Y_{323}	39.5	95
3.2.4 Gross capital formation, % GDP	Y_{324}	23.5	63
3.3 Ecological sustainability	Y_{33}	20.1	115
3.3.1 GDP/unit of energy use, 2005 PPP$/kg oil eq	Y_{331}	2.9	113
3.3.2 Environmental performance	Y_{332}	45.4	101
3.3.3 ISO 14001 environ. certificates/bn PPP$ GDP	Y_{333}	0.4	90
4 Market sophistication	Y_4	45.4	74
4.1 Credit	Y_{41}	23.6	116
4.1.1 Ease of getting credit	Y_{411}	50.0	93
4.1.2 Domestic credit to private sector, % GDP	Y_{412}	46.8	71
4.1.3 Microfinance gross loans, % GDP	Y_{413}	0.0	82
4.2 Investment	Y_{42}	37.1	32
4.2.1 Ease of protecting minority investors	Y_{421}	47.4	102
4.2.2 Market capitalisation, % GDP	Y_{422}	42.9	45
4.2.3 Total value of stocks traded, % GDP	Y_{423}	61.7	17
4.2.4 Venture capital deals/bn PPP$ GDP	Y_{424}	0.0	39
4.3 Trade, competition, and market scale	Y_{43}	75.6	78
4.3.1 Applied tariff rate, weighted mean, %	Y_{431}	3.8	65
4.3.2 Intensity of local competition	Y_{432}	0.3	41
4.3.3 Domestic market scale, bn PPP$	Y_{433}	49.4	121
5 Business sophistication	Y_5	36.1	52
5.1 Knowledge workers	Y_{51}	58.2	34
5.1.1 Knowledge-intensive employment, %….	Y_{511}	40.7	10
5.1.2 Firms offering formal training, % firms	Y_{512}	52.2	24
5.1.3 GERD performed by business, % GDP	Y_{513}	0.7	30
5.1.4 GERD financed by business, %	Y_{514}	27.7	57
5.1.5 Females emp. w/adv. degrees, % tot. emp	Y_{515}	559.7	32
5.1.6 Number of passing the GMAT test / million people.	Y_{516}	66.7	72
5.2 Innovation linkages	Y_{52}	18.9	109
5.2.1 University/industry research collaboration	Y_{521}	40.3	83
5.2.2 State of cluster development	Y_{522}	36.0	108
5.2.3 GERD financed by abroad, %	Y_{523}	4.3	59
5.2.4 JV-strategic alliance deals/bn PPP$ GDP	Y_{524}	0.0	60
5.2.5 Patent families filed in 2+ offices/bn PPP$ GDP	Y_{525}	0.1	47

Table 5 Data of complex structure of GII of Russian Federation (continued)

Indicators	*Identificator*	*Score*	*Rank*
5.3 Knowledge absorption	Y_{53}	31.2	52
5.3.1 Intellectual property payments, % total trade	Y_{531}	6.8	18
5.3.2 High-tech imports less re-imports, % tot. trade	Y_{532}	10.3	45
5.3.3 ICT services imports, % total trade	Y_{533}	5.5	49
5.3.4 FDI net inflows, % GDP	Y_{534}	2.8	73
6 Knowledge and technology outputs	Y_{6}	30.4	48
6.1 Knowledge creation.	Y_{61}	34.6	25
6.1.1 Patents by origin/bn PPP$ GDP	Y_{611}	11.3	13
6.1.2 PCT patent applications/bn PPP$ GDP	Y_{612}	0.4	42
6.1.3 Utility models by origin/bn PPP$ GDP	Y_{613}	5.3	9
6.1.4 Scientific and technical articles/bn PPP$ GDP	Y_{614}	10.6	72
6.1.5 Citable documents H index	Y_{615}	308.0	20
6.2 Knowledge impact	Y_{62}	33.0	77
6.2.1 Growth rate of PPP$ GDP/worker, %	Y_{621}	4.4	21
6.2.2 New businesses/th pop.	Y_{622}	0.8	72
6.2.3 Computer software spending, % GDP	Y_{623}	0.3	45
6.2.4 ISO 9001 quality certificates/bn PPP$ GDP	Y_{624}	5.3	63
6.2.5 High- and medium-high-tech manufactures, %	Y_{625}	22.3	46
6.3 Knowledge diffusion	Y_{63}	25.7	68
6.3.1 Intellectual property receipts, % total trade	Y_{631}	1.6	28
6.3.2 High-tech exports less re-exports, % total trade	Y_{632}	1.1	75
6.3.3 ICT services exports, % total trade	Y_{633}	6.0	72
6.3.4 FDI net outflows, % GDP	Y_{634}	3.6	19
7 Creative outputs	Y_{7}	30.8	101
7.1 Intangible assets	Y_{71}	27.0	125
7.1.1 Trademarks by origin/bn PPP$ GDP	Y_{711}	21.4	63
7.1.2 Industrial designs by origin/bn PPP$ GDP	Y_{712}	0.6	38
7.1.3 ICTs a business model creation	Y_{713}	43.6	121
7.1.4 ICTs and organisational model creation	Y_{714}	43.6	103
7.2 Creative goods and services	Y_{72}	32.2	81
7.2.1 Cultural and creative services exp., % total trade	Y_{721}	0.6	21
7.2.2 National feature films/mn	Y_{722}	2.3	55
7.2.3 Global ent. and media market/th	Y_{723}	7.5	67
7.2.4 Printing and publishing manufactures, %	Y_{724}	1.6	59
7.2.5 Creative goods exports, % total trade	Y_{725}	0.2	93
7.3 Online creativity	Y_{73}	37.1	44
7.3.1 Generic TLDs/th	Y_{731}	4.1	68
7.3.2 Country-code TLDs/th	Y_{732}	50.9	36
7.3.3 Wikipedia monthly edits/mn	Y_{733}	2.864	47
7.3.4 Video uploads on YouTube	Y_{734}	76.8	55

In the report GII-2013 (Solozhentsev, 2016) estimations of the innovation systems of 142 countries on 84 initial indicators in scores and ranks are given. The more a country's innovation system scores (in the range from 0 to 100), the better its innovation system. The ratings change by the other way: the higher score, the lower rating.

Estimations of the derivative indicators of the innovation system of Russia, GII, IIP and IIR, given in Tables 5 and 6, show that Russia is not among the first 30 countries in any IIP group (state, human capital and research, infrastructure, market, business, knowledge and technology, creative outputs). Following groups have lowest ratings: the State – rating 87, the market – 74, the creative yield – 101. Following indicators of IIP groups have low ratings: regulatory environment – 100, credit – 116, trade and competition – 78, 109, impact of knowledge – 77, higher education – 46, intangible assets – 125.

Leaders on GII (Switzerland, USA, Finland), having the highest rank (Table 6), do not aspire to reach the maximum values of score because this is too expensive.

Table 6 Comparison of GII es for various countries

Indexes – indicators	*Switzerland*		*USA*		*Finland*		*China*		*Russia*	
	Score	*Rank*	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*
GII	66.6	1	60.3	5	59.5	6	44.7	35	37.2	62
IIP	66.7	1	51.4	12	52.4	8	44.1	25	30.6	72
IIR	66.5	7	69.2	3	66.7	6	45.2	46	43.8	52
IER	1.0	12	0.7	86	0.8	67	1.0	14	0.7	104
Y_1	87.3	16	86.0	17	95.3	2	48.3	113	56.0	87
Y_{11}	92.7	6	79.3	25	97.9	1	39.2	126	42.9	117
Y_{12}	97.8	6	79.3	44	100.0	1	49.0	106	57.2	100
Y_{13}	90.2	6	77.0	21	100.0	1	41.7	58	68.0	55
Y_2	94.6	12	94.6	13	96.8	6	50.3	116	44.1	33
Y_{21}	92.3	12	88.3	16	95.9	9	44.3	89	62.0	42
Y_{22}	94.7	11	90.2	17	100.0	1	34.8	87	40.0	46
Y_{23}	10.1	39	8.0	1	10.1	39	27.4	118	30.3	31

Score is used to analyse the country's innovation system, but rank – for advertising purposes. We have too many initial indicators – 84, and it is difficult to choose how to manage the country's innovation system. Let consider values of score and we can see there is no country with all scores = 100.0.

GII, IIP and IIR, the first and second level derivative indicators and 84 initial indicators determine the state and attractiveness of the country's innovation system, but they are not enough to manage the innovation system. GII and other derivative indexes are calculated by arithmetic addition with averaging of the initial indicators. Arithmetic addition and averaging of indicators does not allow correctly determine the influence of every initial indicator on GII and derivative indicators.

5.2 LP model of the country's innovation index

The country's innovation index also uses, like the global innovation index, m = 84 independent initial indicators and their connections with derivative indicators and assesses the quality of the country's innovation system. The report of the University of Michigan gives values of initial indicators for 142 countries. Ratings are obtained by values of indicators. Most initial indicators have values within interval [0, 100], which are easily transformed into the interval [0, 1]. Values of other indicators are also transformed into the interval [0, 1], that is, all initial indicators are normalised.

We introduce the concept of 'invalid event' as a deviation of the indicator q_i from a zero or a given value. Let call following condition

$$q_i \geq 0 \tag{15}$$

an 'event of invalidity'. The probability of this event is equal to the value of the indicator. Initial indicators and corresponding events are independent and for the GII system have the same weights

$$w_i = 1/m = 1/84. \tag{16}$$

Normalised initial indicators we will call initiating events, they are equal to

$$q_i = Score^i/100. \tag{17}$$

Criterion

$$P_i = q_i \cdot w_i = (Score_i/100)(1/84) \tag{18}$$

expresses the degree of efficiency of the i-indicator in the GII system and is the probability of the indicator's efficiency.

We introduce identifiers for logical variables according to indicators (Table 6). In accordance with the data structure (Table 3), we write logical functions of efficiency for the derivative events-indicators.

Let calculate logical values of LScore for derivative events-indicators, this operation corresponds to mathematical and common sense. Using the logical addition of initiating events (initial indicators), we obtain correct estimations of score and rank of all derivative events-indicators in accordance with the scheme of connection of events-indicators.

System of logical functions for 21 derivative events-indicators of the second level:

$$\left\{\begin{array}{l} Y_{11} = Y_{111} \vee Y_{112} \vee Y_{113}, \\ Y_{12} = Y_{121} \vee Y_{122} \vee Y_{123}, \\ Y_{13} = Y_{131} \vee Y_{132} \vee Y_{133}, \\ \dots\dots\dots\dots\dots\dots \\ Y_{71} = Y_{711} \vee Y_{712} \vee Y_{713}, \\ Y_{72} = Y_{721} \vee Y_{722} \vee Y_{723}, \\ Y_{73} = Y_{731} \vee Y_{732} \vee Y_{733}. \end{array}\right\} \tag{19}$$

System of logical functions for seven derivative events-indicators of the first level:

$$\left\{\begin{array}{l} Y_{1} = Y_{11} \vee Y_{12} \vee Y_{13}, \\ \dots\dots\dots\dots\dots\dots \\ Y_{7} = Y_{71} \vee Y_{72} \vee Y_{73}. \end{array}\right\} \tag{20}$$

Logical functions of the efficiency IIP and IIR:

$$LIIP = Y_1 \vee Y_2 \vee \ldots \vee Y_5; \quad (21)$$

The relation between global logical and scoring innovation indexes are following:

$$LIIR = Y_6 \vee Y_7.; \quad LII \cdot 100 \rightarrow SII. \quad (22)$$

Explanation. Let we have logical risk function for events:

$$Y = Z_1 \vee Z_2 \vee Z_3 \vee Z_4.$$

Logical risk function in equivalent orthogonal form:

$$\tilde{Y} = Z_1 \vee Z_2 \overline{Z_1} \vee Z_3 \overline{Z_2}\,\overline{Z_1} \vee Z_4 \overline{Z_3}\,\overline{Z_2}\,\overline{Z_1}.$$

Probabilistic risk function:

$$P\{Y\} = P_1 + P_2(1 - P_1) + P_3(1 - P_2)(1 - P_1) + P_4(1 - P_3)(1 - P_2)(1 - P_1),$$

where P_1, P_2, P_3, P_4 – are probabilities of events Z_1, Z_2, Z_3, Z_4.

LP analysis and control of LII and derivative events-indicators are performed by probabilistic models. Quantitative analysis determines significances and contributions of indicators in probabilities of derivative events. Significances of indicators and their combinations are determined from the change of LII probabilities and derivative events when they are excluded (Solozhentsev, 2016).

For innovation system, the management of the LII's state is considered. The management is performed based on results of the analysis of significances of indicators in the following sequence: an assessment of significances of events-indicators, the selection of the most significant of them, the allocation of resources for change of probabilities of these events-indicators. Management of the LII's evolution is made by controlling the movement along the selected trajectory and correcting, if there is deviation from trajectory (Solozhentsev, 2016).

Calculations of logical innovation indexes (LII) were performed. Comparison of the results of calculations using the GII and LII approaches (Table 7) shows global innovation indexes differ, depending on applied approach.

The Logical Innovation Indexes of groups of first-level derivative events are about seven times smaller than LII, and the logical innovation indexes of second-level derivative events are about four times smaller than the first level. The logical innovation index of production (LIIP) is about 2.5 times larger than the logical innovation index of results (in GII the ratio of these indexes is 0.7). Comparison of results shows their harmony with common sense and the rules of LP-calculus (Solozhentsev, 2016).

5.3 Advantages of the LII LP model

LII LP model provides an effective technique for assessing, analysing and managing the country's innovation system. In the international methodology GII (Tables 5 and 6), all derivative indicators at all levels have approximately the same score, equal to the average score of initial indicators (~ 50.0). The effect of the initial indicators is averaged. It is impossible to correctly analyse and manage individual initial indicators.

Table 7 Comparison results by *GII* and *LII* approaches

Indicators	*Identifiers*	*Score*	*Probability of efficiency., P*	**AScore (69)*
Global innovative index	GII	37.2	0.334138	33.4
Innovative index of production	IIP	30.6	0.248174	24.8
Innovative index of results	IIR	43.8	0.114341	11.43
1 State	Y_1	56.0	0.04847	4.847
1.1 Political environment	Y_{11}	42.9	0.015176	1.5176
1.2 Regulatory environment	Y_{12}	57.2	0.009988	0.9988
1.3 Business environment	Y_{13}	68.0	0.02406	2.406
2 Human capital and research	Y_2	44.1	0.051567	5.1567
3 Infrastructure	Y_3	37.2	0.057438	5.7438
4 Market	Y_4	45.4	0.050785	5.078
5 Business	Y_5	36.1	0.06886	6.886
6 Knowledge and technology outputs	Y_6	30.4	0.060265	6.0265
7 Creative outputs	Y_7	30.8	0.057543	5.05754

The offered LP-model of LGII has the following advantages:

1 values of LScore estimations for derivative events-indicators at different levels become different depending on the number of indicators and their probabilities

2 derivative events-indicators of the second and other higher levels have an accurate assessment of their attractiveness and utility and can be used for analysis and management by allocating resources for change their estimations

2 IIP and IIR have different LScore, which corresponds to common sense and the number of indicators which influence them

3 Innovative indexes of groups of events-indicators have correct estimations, since they are calculated without averaging and can be effectively used to manage the country's innovation system.

Currently adopted GII and the proposed LII do not consider all aspects of the effective management of the country's innovation system. It is not clear what needs to be done to improve the quality of the innovation system, and what is the role of the State, business, banks, scientists and public opinion in solving this problem. Answers to these questions can be given by analysis of examples of real innovation development.

6 Simple structure data

LP model for estimation of risk of one innovation failure

The LP model estimates the risk of failure of one innovation and is based on the processing of statistical data of finalised innovation. But this model is used to predict new proposed innovations. Based on the performed analysis of the development and implementation of the innovation 'technologies for risk management of structurally complex systems', indicators of the innovation system failures are given in Table 8.

Table 8 Parameters of innovation system failure

N	*Parameter*	*Identifier*
1	Communication with foreign scientists	Z_1
2	Prioritising fundamental and applied research	Z_2
3	The choice of the concept of development of socio-economic systems and the country	Z_3
4	Involving scientists and public opinion in solving difficult social and economic problems	Z_4
5	Innovative projects with interdisciplinary research	Z_5
6	Borrowing foreign methods, programs and technologies	Z_6
7	Analysis of the desires and capabilities of subjects involved in problem's solution	Z_7
8	Crediting process management	Z_8
9	Financial support of science and innovation projects	Z_9
10	Development a bank of orders for fundamental and applied projects and research from companies and ministries	Z_{10}
11	The share of the country's gross output, which is sent to the fund for investments in innovation and science	Z_{11}

The list of indicators can change as other innovations are developed and implemented. Indicative indicators, characterising innovation system failure, were used for development of an indicative LP model of the risk of the innovation system failure. Indicative events-indicators are demonstrated in large scale, without details. Risks (probabilities) of these events, which determine the innovation system failure, are estimated by expert information, using the method of summarised randomised indexes (Karaseva and Alexeev, 2015).

The indicative LP model of the risk of innovation system failure is red so: the risk of failure occurs: OR due to any single event-indicator, OR due to any two events-indicators, …, OR due to all events-indicators.

Indicative logical model of the risk of innovation system state danger:

$$Y = Z_1 \vee Z_2 \vee Z_3 \vee Z_4 \vee Z_5 \vee Z_6 \vee Z_7 \vee Z_8 \vee Z_9 \vee Z_{10} \vee Z_{11} \tag{23}$$

Indicative probabilistic model of the risk of innovation system state danger:

$$P\{Y\} = R_1 + R_2(1 - R_1) + R_3(1 - R_2)(1 - R_1) + \ldots, \tag{24}$$

where R_n – are risks of events-indicators Z_n, $n = 1, 2, \ldots, 11$.

The methods of LP-analysis and LP-risk management in systems are considered in details in Solozhentsev (2016) and Ryabinin (2007). We merely note that the simple structure of expressions (23) and (24) allows us to consider (in the analysis) that the significances and contributions of initiating events-indicators *Z* in the risk of innovation system failure are proportional to the values of their risk. The management aim is to reduce the risk of most significant initiating events-indicators through structural changes in the economics, science and education and allocation of resources to reduce risks of these events.

7 Software for economic system management

Expa is an expert system for the synthesis of probabilities

LP models with event-statements do not have statistical data for the evaluation of probabilities of events. Such LP models include (Solozhentsev, 2016):

- hybrid LP models with risk scenarios for subjects, solving the problem, and for objects, which are the essence of the problem
- conceptual LP models, where the risk scenario for the system is compiled on descriptions of specialists who understand the essence of the problem
- LP models of quality invalidity
- indicative LP models of risk
- LP models for estimation of management system quality, etc.

Probabilities of events-statements are synthesised on the basis of the method of summarised randomised indexes by non-numerical, inaccurate and incomplete expert information (NII-information) (Hovanov et al., 2009; Karaseva and Alexeev, 2015; Karaseva, 2016).

The expert cannot give accurate estimation of the probability for event. He (she) will do it more accurately and objectively if he (she) will estimate probabilities of 2–4 alternative hypotheses and take into account their weight (the expert is 'rocked').

Let us explain the term 'NII-information'. 'Non-numerical' means ordinal information; the expert may declare the probability of one event is greater than the probability of another event, i.e., inequality. 'Inaccurate' means interval; the expert can say the probability of the hypothesis is, for example, within the interval [0.2; 0.5]. 'Incomplete' means this information, in general, is not enough to determine the required probability uniquely.

The use of the summarised randomised indexes method is associated with computational difficulties due to the search of a large number of variants. This explains the use of *Expa* program, which allows automation the decision-making process under uncertainty.

Expa program is certified and described in details in Karaseva and Alexeev (2015) and Karaseva (2016). *Expa* uses understandable interface with windows. Several experts are involved in the synthesis of the probability of the event. Each expert consistently performs the following actions:

- introduces a list of hypotheses
- assigns allowable intervals of probabilities for hypotheses, that is, specifies interval information
- introduces the relationship between hypotheses (more, less, equal), that is, sets the ordinal information

- accepts (by default) the condition: the sum of probabilities of hypotheses is equal to 1
- assigns the accuracy of the simulation (0.01, 0.02, 0.04). Accuracy establishes interval of possible probabilities of hypotheses [0, 1], has respectively 100, 50 or 25 discrete values, one of them will became the probability of the hypothesis
- starts the calculation of a number of possible solutions (for four hypotheses and the accuracy 0.04 the number of variants will be approximately 316,250)
- starts the calculation of probabilities of hypotheses and their dispersions; the probability of every hypothesis is defined as the mathematical expectation on the interval of its possible values; the dispersion of the probability estimation is equal to half of the interval
- displays the results for the report in Microsoft Word format.

Estimations of probabilities of hypotheses from other experts are obtained successively according to the same algorithm. To determine the summarised assessment for all experts, following actions are performed in the screen form:

- introduce a list of experts
- designate acceptable intervals for weights of each expert
- enter probabilities of hypotheses from each expert
- set preference rules for experts
- designate the accuracy of the simulation (0.01, 0.02, 0.04)
- accept (by default) the condition the sum of experts' weight is equal to 1
- start the calculation
- values of the summarised estimations of probabilities of hypotheses are displayed on the screen and in the report.

Among summarised estimations of probabilities of hypotheses, a hypothesis is chosen from all experts having the greatest probability.

ARBITER – the software for structural and logical modelling is adapted for the automated construction of LP models, calculation and analysis of the safety and quality criteria for structural complex systems. ARBITER is based on the general logic-probabilistic method of system analysis and implements the technology of automated structural logical modelling of complex systems (Mozhaev, 2008).

ARBITER is certified by Rostekhnadzor of Russia in 2007 and is the first domestic software implementing new technology of LP analysis (modelling and analysis of safety and quality criteria for structural complex systems).

For the modelling and management of structural complex systems in the economics, the adapted ARBITER was developed (the conventional name is ARBITER-AT), which is being tested in educational and research organisations in St. Petersburg. In comparison with the full version, ARBITER-AT allows LP modelling in static mode only. This software allows modelling of tasks with large dimension and the same accuracy of algorithms like full version. Adapted ARBITER-AT is intended for use in educational purposes, it has changed screen interface with replacing terms from the field of reliability analysis in technology with terms of general LP modelling.

ARBITER-AT uses a graphical interactive interface. Software is described in details in the manual for practical works about the modelling and analysis of the safety and quality of structural complex systems in the economics (Karaseva, 2016; Mozhaev, 2008). Students study ARBITER-AT during two hours of the first lesson with practical work. At following sessions they perform two practical works. They have constructed LP-models and studied more than 100 different structural complex systems in economics. In practical works, students, in addition to selected research, were offered following topics:

1. the risk of failure in modernisation of the economics of the Russian Federation
2. risk of the company's development failure
3. risk of the depreciation of the Euro
4. risk of failure of the activity and choice of the president
5. risk of reducing the profit of the enterprise
6. risk of the global crisis
7. the risk of political instability in the country
8. the risk of popular excitement in the Russian Federation
9. risk of company's marketing strategy failure
10. risk of oil prices decreasing
11. the risk of failure in a difficult economic problem solution, etc.

8 Digital management and network

The basis of the digital management of structural complex systems is mathematical models and corresponding software (Solozhentsev, 2017, 2018). The requirement for digital management is caused by following reasons:

1. tasks of structural complex systems management in the economics are the most relevant and prevalent both at the top level of management, and at the level of regions, cities and enterprises
2. management tasks differ by the complexity, novelty of mathematical methods and use of intellectual knowledge
3. management tasks have large arithmetic and logical computational complexity and without special software are not solved
4. management tasks are solved both from time to time and in the dynamic mode
5. wide and rapid implementation of solutions in economics.

Let's define digital management of structural complex systems in economics by following terms:

- *the purpose* is the maximal safety criterion and the maximal criterion of system quality
- *use of intellectual knowledge* – Boolean event-statements, failure risk scenarios for systems and events, LP risk models, examples of applications
- *objects (systems) of management* are structural complex systems in the economics
- *software* for construction and analysis, LP risk models
- *computer network* for transfer scenarios of system's failure, LP models of system's risk and results of analysis and management.

Digital management of structural complex systems in economics, unlike the existing management based on ephemeral methods and ephemeral objects, uses new intellectual knowledge, unified methods, mathematical models and special software.

Computer network for management

A computer network is a set of computers connected by information transfer channels, necessary software and hardware for distributed information processing.

In a network, connected devices are used to send or receive information. Local computer networks operate at a distance from several metres to several kilometres. Usually they cover the computers of one organisation or enterprise. Global computer networks include a large number of computers in large territories, covering entire regions, countries and continents. For information transfer, fibre-optic backbones, satellite communication systems and switched telephone networks are used. An example of combination global and local networks is the internet.

A computer network for digital management of structural complex systems in the economics has a unified system of intellectual knowledge, models, technologies and software.

In particular, the computer network should have following components:

- computers
- intellectual knowledge: event-statements, scenarios of system failure risk, LP risk models and examples of applications
- special software for construction LP risk models, analysis and management
- internet connection
- a course of additional education for economists and teachers.

9 Conclusions

1. The technique for transformation of a database into a knowledge base (a system of logical equations) is described based on the introduction of events-gradations for parameters of the system's state.
2. Examples of DB used for construction of LP-models of a bank's credit risk and risk and efficiency of a restaurant are given.

3 The example of using complex structure data for construction of a risk LP model and management the country's innovation system is given.

4 The example of using simple structure data and construction of an LP model for risk assessment of one innovation failure is given.

5 Special software *Expa* and *Arbiter* for management of safety and quality in economics are described.

6 The term 'digital management' is defined and components of a computer network for digital management of safety and quality of systems in economics are given.

References

Hovanov, N., Yudaeva, M. and Hovanov K. (2009) 'Multicriteria estimation of probabilities on the basis of expert non-numerical, inexact and incomplete knowledge', *European Journal of Operational Research*, Vol. 195, No. 3, pp.857–863.

Karasev, V. (2015) 'Monitoring and crediting process control with use of logical and probabilistic risk model', *International Journal of Risk Assessment and Management*, Vol. 18, Nos. 3/4, pp.222–236.

Karaseva, E.I. and Alexeev V.V. (2015) 'Synthesis and analysis of probabilities of events by non-numeric, inaccurate and incomplete expert information', *International Journal of Risk Assessment and Management*, Vol. 18, Nos. 3\4, pp.222–236.

Karaseva, E.I. (2016) *Tekhnologii upravleniya riskom. Metodicheskie ukazaniya po vypolneniyu laboratornyh rabot [Risk Management Technologies. Guidance for Practical Works]*, Sankt-Peterburgskij gosudarstvennyj universitet aehrokosmicheskogo priborostroeniya, Vol. 84 (in Russian).

Mozhaev, A.S. (2008) 'Annotacija programmnogo sredstva 'ARBITR' (PK ASM SZMA) [Software 'Arbiter' (PK ASM SZMA) annotation]', *Nauchno-tehnicheskij sbornik «Voprosy atomnoj nauki i tehniki. Serija «Fizika jadernyh reaktorov»*, M:. RNC «Kurchatovskij institut, in Russian, No. 2, pp.105–116.

Ryabinin, I.A. (2007) *Nadezhnost' i bezopasnost' strukturno-slozhnyh sistem (2-e izd.) [Reliability and Safety of Structural Complex Systems]*, 2nd ed., SPb.: Izd-vo S.-Peterb. un-ta., 276pp (in Russian).

Solozhentsev, E.D. (2016) *Top-ehkonomika. Upravlenie ehkonomicheskoj bezopasnost'yu*, 2-e izd., 272pp, Troickij most., SPb, in Russian.

Solozhentsev, E.D. (2017) 'K voprosu cifrovogo upravleniya gosudarstvom i ehkonomikoj [About digital management by state and economics]', *Problemy analiza riska*, in Russian, Vol. 14, No. 6, pp.39–43.

Solozhentsev, E.D. (2018) 'Top-economics: management of socio-economic safety', *Special Issue: Management of Safety in Socio-Economic Systems, Int. J. of Risk Assessment and Management*, Vol. 21, Nos. 1/2, pp.65–88.