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Ability of Logical and Probabilistic Model for Operational Risk Management

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Abstract

In this paper the application of logical and probabilistic (LP) models for operational risk estimation in bank is described, the method for economic capital calculation to cover losses, caused by operational risk, with top and bottom capital limits is offered. The influence of repeated events on credit and operational risks is demonstrated. Significances of such repeated events are higher and actions to their minimization should be top-priority.

Keywords: *bank, management, operational risk, credit risk, structural risk model, logical model, probabilistic model, probability, analysis, business line, economic capital.*

I. Operational risk… What's problem ?

Quality increase, cost reducing, issue of new bank products and services are impossible without upgrading of the risk management framework in a bank. Operational risk plays large role. It leads to financial, human, reputation losses. Operational risk can take place in any bank activity but its realization influences on functioning of whole bank and values of profits. Main feature of operational risk is fundamentality. Operational risk can lead to other risks. We observe in detailed consideration: the reasons of any risk are the human factor, business process defects, technical system failure or external factors. All these reasons are operational risk factors [1]. Moreover, we can suppose the following: the higher operational risk, the higher other bank risks and more losses. Operational risk is the indicator of the bank reliability and reflects the personnel qualification level and possibility of counteraction to unfavorable events.

In comparison with financial risks, operational risk is realized in *events:* power system failure, personnel mistake, flood, earthquake or terrorism actions. Elimination of these events or minimization of consequences requires large resources. Volume of resources should be calculated and resources are reserved beforehand to save a bank from bankruptcy in case of unfavorable events. Operational risk events have accumulative nature, they are similar to "snow ball". In bank's activity some ordinary mistakes and failures occur daily. If personnel will not pay attention to ordinary events, bank administration will finally face consequences, which can be eliminated with large expenses only. Also, another problem is: banks try to hide appeared operational risk events in order to save reputation.

Problem of estimation and identification of operational risk in bank is very complex. Operational risk is caused by different factors and difficult for formalization and modeling. Existing methods of operational risk estimation are used for solution of particular tasks within one business process. Determination of risk value within one business process is not correct, it would be better to determine risk value in interconnection with other bank processes and systems.

Operational risk leads to market and credit risks [2]. Influence and "interaction" of the operational risk with other risks can cause large expenses and reputation loss. Central banks formulate task of development of internal procedures and systems, providing allocation of necessary resources (economic capital), which will equal to business goals of bank, volume of performed operations and risk profile. System for operational risk estimation should be integrated in risk management processes in bank and results should be a part of monitoring process and operational risk profile control [3].

Important task is integration of all risk models in one general model for estimation of "total risk" of bank. This allows calculate integrated risk value (risk index) for bank. Risk index is useful for owners, partners, and Bank's Management Board.

Basel III regulatory framework allows calculates economic capital more precisely [4]. New demands appoint the use of advanced methods only for credit risks while but this event causes banks to develop and implement their internal risk estimation technologies. The Basel Committee on Banking Supervision (BCBS) pays large attention to operational risk. Thus, in Basel III the estimation of economic capital adequacy is equal to coefficient 12,5 (the same coefficient is applied for market risk estimation) rather than 10, as earlier. Basel III cause banks to realize less risky politics, spend money for personal training and implementation of IT systems in order to reduce technological and administrative losses. However, in period of Basel III framework realization the value of operational risk will probably increase.

II. How to formalize operational risk ?

Let consider the logical and probabilistic (LP) model for operational risk estimation [5].

LP-model is constructed with use of the event classification, assigned by BCBS.

In advanced approach every business line is considered separately. In every business line seven kinds of unfavorable operational risk events are considered: internal fraud Z_1; external fraud Z_2; personnel policy and labor safety Z_3; clients, products and business practice Z_4; physical damage of assets Z_5; faults in business and system failures Z_6; execution, delivery and process control Z_7. These are *derivative events*. Every event from $Z_1, \ldots, Z_7$ is caused by concrete elementary events, i.e. *initiating events*. Initiating events are considered as independent casual events. In overall, 98 events were entered. Final derivative event Y is possible losses at business line. The number of initiating events for every business line is equal to 70 and they are the same by description but their probabilities for every business line will be different. Logical variable corresponds to every initiating event. This variable takes values 1 or 0 (events will occur or not) with the certain probability. Initiating events have probabilities of occurrence. These probabilities can be obtained from statistical data accumulated during last period of bank's activity (Basel II Accord recommended three years long period) or by expert way (in case of absence of statistics) [6,7].

Structural, logical and probabilistic risk models are constructed for every business line.

Structural risk model for one line. As example, let consider first business line of bank (Corporate Finance). We construct the structural model and write the logical function of risk for seven kinds of unfavorable events Z_1, Z_2, Z_3, … Z_7 (fig. 1).

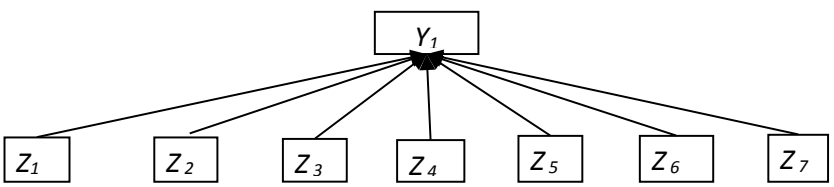

Figure 1. Structural model of operational risk for first business line (Corporate Finance).

Structural model is a *risk scenario*. Scenario is formulated so: event Y_1 (losses at first business-line) will occur if event Z_1 or event Z_2, or Z_3, …, or Z_7 will occur. By other words, Y_1 will occur if, at least, any one event from set $Z_1,\ldots, Z_7$, will take place, or any combination of events, or all of them will occur at the same time (probability of such variant is very small but not equal to 0). Let $Z_1,\ldots, Z_7$ are logical variables, every Z_j, j = 1, 2,…,7 is equal 1 (if events took place) or equal to 0 (in opposite case) with some probability.

Logical operational risk model for seven kinds of unfavorable events $Z_1, Z_2,\ldots, Z_7$ of operational risk for first business line is written in *disjunctive normal form* by following way:

$$Y_1 = Z_1 \vee Z_2 \vee Z_3 \vee Z_4 \vee Z_5 \vee Z_6 \vee Z_7. \quad (1)$$

In order to obtain *probabilistic model* we have to write equation (1) in *orthogonal disjunctive normal form*. This operation is not simple. Here we are faced with problem of fast increasing of function dimension and we are not stating intermediate mathematical expressions in this paper due to large volume. Methods and procedures of orthogonalization are described in [8]. After orthogonalization procedures we obtain orthogonal logical function

$$Y_1 = Z_1 \vee Z_2 \bar{Z}_1 \vee Z_3 \bar{Z}_1 \bar{Z}_2 \vee Z_4 \bar{Z}_1 \bar{Z}_2 \bar{Z}_3 \vee Z_5 \bar{Z}_1 \bar{Z}_2 \bar{Z}_3 \bar{Z}_4 \vee Z_6 \bar{Z}_1 \bar{Z}_2 \bar{Z}_3 \bar{Z}_4 \bar{Z}_5 \vee$$
$$\vee Z_7 \bar{Z}_1 \bar{Z}_2 \bar{Z}_3 \bar{Z}_4 \bar{Z}_5 \bar{Z}_6$$

where logical variables and signs of logical operations can be substituted with corresponding probabilities and signs of arithmetical operations. In result, we obtain probabilistic operational risk model:

$$P\{Y_1=1\} = P(Z_1)+P(Z_2)(1-P(Z_1)) + P(Z_3)(1-P(Z_1))(1-P(Z_2)) +$$
$$+ P(Z_4)(1-P(Z_1))(1-P(Z_2))\ (1-P(Z_3)) + P(Z_5)(1-P(Z_1))(1-P(Z_2))(1-P(Z_3))(1-P(Z_4)) +$$
$$+ P(Z_6)(1-P(Z_1))(1-P(Z_2))(1-P(Z_3))(1-P(Z_4))(1-P(Z_5)) +$$
$$P(Z_7)(1-P(Z_1))(1-P(Z_2))(1-P(Z_3))(1-P(Z_4))(1-P(Z_5))(1-P(Z_6)). \quad (2)$$

Probabilistic risk model for one business line permits calculate the probability of losses at this business line if probabilities of initiating events are known.

Such models are constructed for eight business lines to calculate probabilities of events $Y_1, \ldots, Y_8$.

Let construct probabilistic model for calculation of bank's operational risk. Operational risk of bank is logical sum of probabilities of losses at eight business lines.

Structural operational risk model is represented at fig. 2.

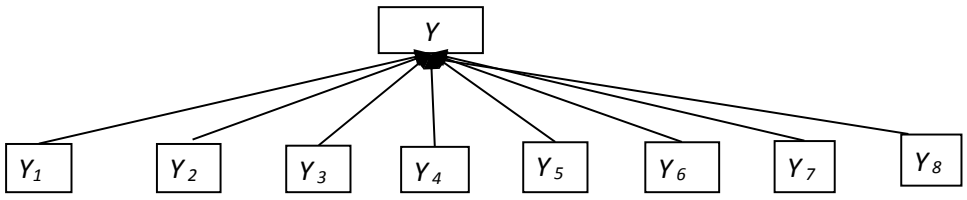

Figure 2. Structural model of bank's operational risk.

Logical model of bank's operational risk in disjunctive normal form is following:

$$Y = Y_1 \vee Y_2 \vee Y_3 \vee Y_4 \vee Y_5 \vee Y_6 \vee Y_7 \vee Y_8, \quad (3)$$

where:
Y- bank's operational risk,
Y_i – event on i bank's business-line, $i = 1,\ldots,8$.

We obtain probabilistic model from logical model by orthogonalization way:

$$P\{Y=1\}=P_1+P_2(1-P_1)+\ldots+P_8(1-P_1)(1-P_2)(1-P_3)(1-P_4)(1-P_5)\,(1-P_6)(1-P_7). \quad (4)$$

Note, this model can be applied for estimation of bank operational risk by the standardized approach with use of values $P(Y_1)$, $P(Y_2)$, …, $P(Y_8)$ instead of coefficients β in formula of capital resevation. Such modified formula permits determine the volume of the capital for covering losses more precisely because it takes into account functioning features of the concrete bank in comparison with coefficients β, averaged on whole branch [9].

In practice, we don't need use classification of events, offered by Basel II Capital Accord. LP-models can be adopted for business lines and kinds of events in concrete bank. For example, in some Russian banks the additional ninth business line is used. Events, which were not classified on eight standard business lines, are referred to ninth business line. Basel II Capital Accord recommends refer these events to line where the most profit is.

III. How to calculate economic capital volume ?

In general case, for calculation of economic capital we have to calculate probabilities $P_{i,j,k}$ and losses $L_{i,j,k}$ for every initiating event $Z_{i,j,k}$ by statistical data. Here:
$i = 1,2,\ldots,8$ – the number of business line;
$j = 1, 2,\ldots,7$ – kind of events;
$k = 1,2,\ldots,N_j$ – initiating events indexes in j-kind of events:
$N_j = 2 \div 20$ – the number of initiating events of the kind j.
Initiating events probabilities are calculated by formula:

$$P_{i,j,k} = N_{i,j,k} / N, \quad (5)$$

where: $N_{i,j,k}$ – the number of appearance of losses at business line i due to reason j and initiating event k; N – the number of operations at the business line of the bank in considered time interval.

Estimation of economic capital volume consists of two parts: expected and unexpected losses. Economic capital for expected losses EL is calculated by statistics and can be obtained by summarizing of all losses per a year (true economic capital):

$$EL = \sum_{i=1}^{8}\sum_{j=1}^{7}\sum_{k=1}^{N_j} L_{i,j,k}, \quad (6)$$

where $L_{i,j,k}$ - summarized losses due to realization (or several realization) event k of kind j at business line i during report period (for example, one year).

Unexpected losses UL^{LP} is suggested to estimate by formula of predictable damage for technical systems [10]:

$$UL^{LP} = P_Y L_{max}, \quad (7)$$

where: P_Y - operational risk of bank is calculated by equation (4),

L_{max} – maximal possible loss at business line, concrete operation (transaction) or in bank as a whole, depending from modeling level.

Risk-manager should decide what losses will be chosen as L_{max}, proceed from the situation. Gross receipt at business line, maximal losses at business line or operation (transaction) can be chosen, or L_{max} can be given on basis of expert evaluation also.

Economic capital volume is calculated by formula:

$$R_{Sub}{}^{LP} = EL + UL^{LP}. \quad (8)$$

Value $R_{sub}{}^{LP}$ is bottom limit of economic capital.

The basic indicator approach determines economic capital for operational risk of bank have to be 15% of average gross receipt of bank during three years. For analysis we have to know top limit of possible losses from unfavorable economic situation and unforeseen rare events [11].

Top limit estimation of the reserved capital is performed proceed from the integrated risk of the bank as a whole:

$$R_{Sup}{}^{LP} = P_Y Q, \quad (9)$$

where: Q – gross receipt of the bank;

P_Y – the probability calculated by probabilistic model (4).

Evaluations by (6), (8) and (9) will be different. Choice of the formula depends on data and expenses of data obtaining. Formula (6) estimates real losses of last years. Formula (8) gives bottom limit of reserved capital under known losses. However, in practice it is difficult to estimate precisely the value of losses due to operational risk event, therefore, we need to know top limit of possible losses. In case of unstable economic and political situation we recommend use formula (9) for calculation of maximal value of economic capital, using the volume of bank's profit which can be lost in case of unfavorable events. Choice of formula depends on situation and this is duty of risk-manager.

IV. Towards to integration

The advantage of LP operational risk model is possibility to unite with other LP risk models. This allows develop a complex model to calculate integrated risk index of a bank.

In activity of any bank there are events that influence on several risks in same time. These events are called "repeated". Losses from repeated events have to be fixed in connection with those risks that were influenced by them. If they influence on several risks then the economic capital is made for every risk. In this case we have too large double economic capital. Of course, if there are several owners of the risk then every owner is responsible. But risk-managers have to pay large attention to these events. We offer to construct the LP risk model with repeated events influencing on several processes simultaneously. The complex LP risk model in bank with logical operations AND or OR, uniting LP operational risk model with LP models of other risks, allows perform quantitative estimation of integrated risk of bank and mark out repeated elements which influence on several risks at once [12].

Operational risk value may be considered as the index of bank's reliability. With small percent (about 5 %) [13] it influences significantly on all bank risks. So, operational risk estimation is important problem and good management of operational risk help to reduce losses from other risks.

Let construct the united LP-model of operational and credit risk with logical connection AND (fig. 3).

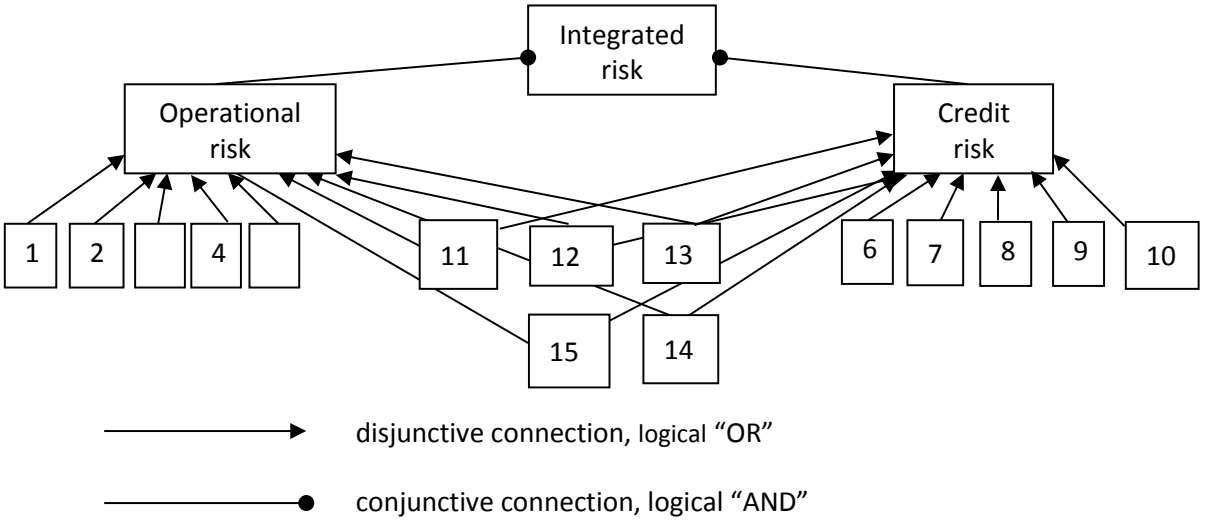

Figure 3. United model of operational and credit risks

where:
1- clients, products, business practice;
2 – operations and process control;
3 – damage of material assets;
4 – organizational violations and system failures;
5 – data transmission process violation;
6 – wrong technique of credit risk estimation;
7 – wrong credit portfolio estimation;
8 – wrong calculation of economic capital volume;
9 – mistake in guarantee estimation;
10 - accident with borrower;
11 - fraud;
12 – economic situation changing;
13 – mistakes in registration of borrower's application;
14 – inaccurate information given to borrower;
15 – mistake in management of bank risks.

Let mark out five events - 1, 2, 3, 4, 5 for operational risk, and events 6, 7, 8, 9, 10 for credit risk. Events 11, 12, 13, 14, 15 are repeated for operational and credit risks. To simplify the calculation, let event 11 is external and internal fraud together.

Under the united structural model (fig.3) we write the logical risk model:

$$Y = Y_{OpR} \wedge Y_{CredR}, \quad \text{or}$$

$$Y = (Y_1 \vee Y_2 \vee Y_3 \vee Y_4 \vee Y_5 \vee Y_{11} \vee Y_{12} \vee Y_{13} \vee Y_{14} \vee Y_{15}) \wedge (Y_6 \vee$$
$$\vee Y_7 \vee Y_8 \vee Y_9 \vee Y_{10} \vee Y_{11} \vee Y_{12} \vee Y_{13} \vee Y_{14} \vee Y_{15}) \quad (10)$$

Probabilistic functions, written for operational and credit risks separately, will look like function (4). Integrated risk is obtained by multiplication values $P(Y_{OpR}=1)$ and $P(Y_{CredR}=1)$.

Let calculate, for analysis, probabilities of operational and credit risks and integrated risk (table 1) without repeated events 11-15. Further, we enter other events gradually, one by one, make calculations on changing models and fix the changing of integrated risk. Integrated risk will change on some value. This value is *contribution of event* in risk. In table 1 probabilities of initiating events are presented. Probabilities of events were obtained by experts with use of the method of summarized indexes [7, 14], taking into account the percent of operational risk in Russian banks is 5% [13]. Expert estimation were obtained by same method for credit risk also but taking into account the average risk of credit portfolio is 25% and was recognized as satisfactory[1].

Table. 1. Results of calculations on model with repeated events.

Event	1 variant (without repeated event)	2 variant (1 repeated event)	3 variant (2 repeated events)	4 variant (3 repeated events)	5 variant (4 repeated events)	6 variant (5 repeated event)
Clients, products and business practice	0,00146	0,00146	0,00146	0,00146	0,00146	0,00146
Operation and process control	0,0138	0,0138	0,0138	0,0138	0,0138	0,0138
Damage of material assets	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015
Organizational violations and system failures	0,00041	0,00041	0,00041	0,00041	0,00041	0,00041
Data transmission process violation	0,022	0,022	0,022	0,022	0,022	0,022
Wrong technique of credit risk estimation	0,05677	0,05677	0,05677	0,05677	0,05677	0,05677
Wrong credit portfolio estimation	0,051323	0,051323	0,051323	0,051323	0,051323	0,051323
Wrong calculation of economic capital volume	0,036733	0,036733	0,036733	0,036733	0,036733	0,036733
Mistake in guarantee estimation	0,050401	0,050401	0,050401	0,050401	0,050401	0,050401
Accident with borrower	0,016759	0,016759	0,016759	0,016759	0,016759	0,016759
Fraud		0,0191	0,0191	0,0191	0,0191	0,0191
Economic situation changing			0,0054	0,0054	0,0054	0,0054
Mistakes in registration of borrower's application				0,0041	0,0041	0,0041
Inaccurate information given to borrower					0,00024	0,00024
Mistake in						0,00518

[1] This was obtained by expert way to demonstrate calculations.

Event	1 variant (without repeated event)	2 variant (1 repeated event)	3 variant (2 repeated events)	4 variant (3 repeated events)	5 variant (4 repeated events)	6 variant (5 repeated event)
management of bank risks						
OR	0,0387473	0,057103	0,062195	0,06604	0,066264	0,071101
CR	0,195209	0,210581	0,214844	0,218063	0,218251	0,2223
Integrated risk	0,007563	0,026519	0,031775	0,035745	0,035977	0,04097

Contributions of repeated events are presented in table 2.

Table 2. Contribution of repeated events in changing of risks

Risk	Risk without repeated events, %	Contribution of event 1 in changing of risk	Contribution of event 2 in changing of risk	Contribution of event 3 in changing of risk	Contribution of event 4 in changing of risk	Contribution of event 5 in changing of risk	Difference between final result and primary result
OR	3,87473	1,8087	0,5043	0,3824	0,0223	0,4837	3,23537
CR	1,95209	1,5114	0,4222	0,3202	0,0187	0,4049	2,7091
Integrated risk	0,7563	1,8674	0,5207	0,3948	0,023	0,4993	3,34

Repeated event make different contributions in operational and credit risks. At the same time the operational risk has increased on 3,23 percentage points due to repeated elements, credit risk - on 2,7 percentage points and integrated risk - on 3,34 percentage points.

Significances of initiating events for final event are presented in table 3.

Table 3. Significances of events for final event

Number of the initiating event	Significance of the event
1	+1.81595E-01
2	+1.83867E-01
3	+1.81602E-01
4	+1.81404E-01
5	+1.85409E-01
6	+3.1944E-02
7	+3.17609E-02
8	+3.12798E-02
9	+3.17300E-02
10	+3.06444E-02
11	+9.77704E-01
12	+9.64237E-01
13	+9.62978E-01
14	+9.5926E-01
15	+9.64023E-01

As result we have obtained, repeated events that are initiating events for several risks have larger significance for final event.

Integrated risk can be used as bank risk index. It allows classify bank in corresponding category of quality, reliability and safety. This is useful for investors, creditors, partners and other

interesting persons. Also, risk index allows to compare banks with each other.

V. Conclusion

Above-mentioned models are simple but they reflect the sense of the approach, based on tree of events, logics and probability theory. LP method is flexible and allows adopt models for concrete bank without limitation of event classification, suggested by Basel II Capital Accord. For example, in (Karaseva, 2012) there is a model of internal fraud in bank, describing this problem more detailed. Internal fraud model can be included in model (3) to increase the accuracy of operational risk estimation and economic capital calculation.

Advantage of LP-model is possibility to analyze of operational risk (determination of events with largest contribution in losses) and analyze repeated events, which provide contributions in different risks. Taking into account repeated elements gives the more accurate estimation of integrated risk of bank. Integrated risk can be used for management purposes and classification.

Offered approach is simple, transparent, understandable for bank personnel and does not require large expenses of money and resources. However, it can be realized only with a system of effective monitoring of operational risk (events have to be fixed). It is necessary to provide strict event classification in a bank (or use ready event classification from Basel II) in order to every initiating events will be classified to certain kind of certain business line without any doubts.

Main serious problem in realization of logical and probabilistic technique of estimation and analysis of operational risk is providing of good motivation of bank's employers to fix events without fear for their personal mistakes. Every employer has to fix occurred events promptly and pass reports to operational risk manager. The manager classifies events and inputs in database. Database information is used for regular re-training of model (calculation of probabilities of initiating events) in order to take into account change of economic situation and internal processes conditions and keep necessary accuracy of estimation.

References

[1] Karaseva E.I. Determination of Rating of Bank on Basis of Risk Values / Proceedings of III International Scientific and Methodical Conference "Mathematical Methods, Models and Information Technologies in Economics. – Ukraine, Chernivtsy: DrukArt, 2013 *(In Russian)*

[2] Frumina S.V. Risks of Commercial Bank Influencing on Economic Safety: Modern Minimization Practice. Risk Analysis Problems. Vol. 7, № 2, 2010, pp. 66-77. *(In Russian)*

[3] WebSite of Central Bank of Russian Federation - URL: http://www.cbr.ru *(In Russian)*

[4] Basel III: A global regulatory framework for more resilient banks and banking systems December 2010 (rev June 2011) Basel Committee on Banking Supervision http://www.bis.org/publ/bcbs189.pdf

[5] Karaseva E.I. Logical and Probabilistic Model for Estimation of Operational Risk of Bank and Economic Capital. Risk Analysis Problems. Vol. 9, № 2, 2012, pp. 24-34. *(In Russian)*

[6] Hovanov N., Yudaeva M., Hovanov K. Multicriteria estimation of probabilities on basis of expert non-numeric, non-exact and non-complete knowledge. European Journal of Operational Research. Vol. 195, Issue 3, 2009 pp. 857-863.

[7] Karaseva E., Alexeev V. Synthesis and analysis of probabilities of events by non-numeric, inaccurate and incomplete expert information // Int. J. of Risk Assessment and Management, Vol. 18, No 3/4, 2015, pp. 276-287.

[8] Ryabinin I.A., 2007. Reliability and Safety of Structural Complex Systems. 2nd Edition, SPb.: Saint-Petersburg State University Publishing. 276 p. *(In Russian)*

[9] Moscadelli M. The Modeling of Operational Risk: Experience with the Analysis of the Data Collected by the Basel Committee. Working paper Banco de Italia. Num. 517, July, 2004.

[10] Polenin V.I., Ryabinin I.A., Svirin S.K., Gladkova I.A. Application of Logical and

Probabilistic Method of Analysis of Technical, Military, Organizational and Functional Systems and Armed Opposition. Edited by Mozhaev A.S. SPb.: SPb regional division of RANS, 2004, 416 p. *(In Russian)*

[11] Taleb N.N. The Black Swan: The Impact of the Highly Improbable, 2nd ed., New York: Penguin Books, 2010.

[12] Karaseva E.I. Analysis of Contributions of Events in Operational Risk of Bank. Scientific and Technical News of SPbSPU. Series "Economics". № 3, 2012, pp. 151-154. *(In Russian)*

[13] Expert RA. Risk Management in Russian Banks, 2006. URL: http://www.risk-manage.ru/conference/material/bank.pdf *(In Russian)*

[14] Hovanov N.V., Yudaeva M.S. Use of Randomized Probabilities Method for Estimation of Expectant Values and Variations of Financial and Economic Indicators. Proceedings of International Scientific School MASR - 2010 (Saint-Petersburg, June 28 – July 02, 2010). - SPb.: SUAI, SPb., 2010, pp. 114-122. *(In Russian).*