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O. Yu. Churikanova, Cand. Sci. (Econ.),
K.Ye. Tukhmenova,
M.O. Kharchenko

State Higher Educational Institution "National Mining University", Dnipropetrovsk, Ukraine, e-mail: elen.c@mail.ru, tyukhmeneva@gmail.com, makharchenko@mail.ua

IMPROVING THE ACCURACY OF PREDICTION OF FOREIGN EXCHANGE RATES ON THE INTERNET MARKET BY MEANS OF NEURAL NETWORKS

О.Ю. Чуріканова, канд. екон. наук, доц.,
К.Є. Тюхменьова,
М.О. Харченко

Державний вищий навчальний заклад „Національний гірничий університет", м. Дніпропетровськ, Україна,
e-mail: elen.c@mail.ru; tyukhmeneva@gmail.com;
makharchenko@mail.ua

ПІДВИЩЕННЯ ТОЧНОСТІ ПРОГНОЗУВАННЯ КУРСІВ ВАЛЮТ НА ІНТЕРНЕТ РИНКУ ЗА ДОПОМОГОЮ НЕЙРОННИХ МЕРЕЖ

Purpose. Development and construction of economic-mathematical forecasting model of exchange rates by means of neural networks for definition of exchange rates behavior on the Internet market taking into account factors of technical and fundamental analyses.

Methodology. For solution of this goal methods of the comparative analysis, systematic comprehensive approach and methods of economic-mathematical modeling by means of neural networks were used.

Findings. Research of major factors by tools available to do a forecast concerning fluctuations of exchange rates in the future was carried out. We have defined that the exchange rates behavior is influenced by rather large number of factors relating to methods of fundamental and technical analyses. It was established that any factors cannot guarantee 100% reliability in a forecast. Only application of a comprehensive approach insures high degree of forecast accuracy. Economic-mathematical forecasting model of exchange rates with the neural networks for the purpose of implementation of a comprehensive approach was offered and constructed. It has allowed complex indicators of fundamental and technical analyses. On the basis of technical and fundamental analyses indicators of exchange rates behavior on the Internet market the group of factors which have numerical measurement was created. Justification of mathematical apparatus of neural networks as optimum for construction economic-mathematical model for the performance of forecasts and taking into account the purpose put in this work was executed. On the basis of the created group of factors construction of economy was executed - mathematical model of funds of neural networks, for which entrance data on the selected factors move and on exit look-ahead value of exchange rates turns out.

Originality. Construction of economic-mathematical forecasting model of exchange rates for Internet market was executed by neural networks which unlike the existing considering groups of ten factors, such as: the index of the relative size of the prices, the index of simplification of the market, the index of Dow Jones, the "Standard and powers" index, the New York stock exchange index, indices of the American stock exchange, the RSI indicator, the average index of the directed movement ADX, the index of off-exchange turn, the stochastic indicator.

Practical value. The practical significance of these results is the possibility of increasing the accuracy of the forecast of exchange rates on the Internet market by the use of advanced mathematical apparatus, which was based on the expanded set of factors affecting the fluctuations of exchange rates.

Keywords: *forecasting of exchange rates, neural networks, fundamental analysis, technical analysis, Internet trading*

Statement of the problem. Today, due to development of mass media, improvement of computers and Internet technologies, work of the trader became much simpler thanksto Internet trading. It has simplified because the necessary information became more available, now it is possible to obtain data on exchange rates, market trends, about new strategy much easier. Such operations as bid or sale of currencies have become simpler, now agreements occur much quicker and more simply.

The currency market as well as any others shows complex economic system in which different processes proceed. Many of these processes are studied quite well and are giving in to standard mathematical calculation. But there are also such processes the emergence of which is caused by existence of different random factors and to describe them with known mathematical and economic regularities is rather a difficult process.

Analysis of the recent research and publications. There are no publications devoted to studying and forecasting of currencies behavior for the market Internet. Among them it is necessary to highlight works of such authors as Stephen B. Akelis, Robert Colby, Thomas A.Meyers, T.Demark, D. Piskulov E. Peytel, P. Peytel and many other.

Application of methods and the tools of analysis described by authors marked out above definitely give rather

high accuracy ofcurrency behavior forecast in the market and the Internet trading is very widely used in modern practice. But, in spite of the fact that certain results in this area have already been reached, the problem of forecastaccuracy increase and alsowork stability of analysis principlesis topical. Performance features of currencies existing methods forecast are the trader, applying this or that method of the analysis, it can insure forecast accuracy reaching up to 90%, and subsequently, using the same method of the analysis, to get accuracy close to zero. It is caused by the fact that the complex market of currencies processes proceeds describing standard mathematical regularities [1]. To analyze the Internet currency market this work is also devoted to updating of approaches.

For better understandingthe Internet currency market regulations it is necessary to carry out a number of analyses, including technical and fundamental ones [2–5].

As a whole it is possible to define the technical analysis, as a method of price forecasting, based on mathematical, instead of economic exposition. This method has been created for purely applied purposes, namely obtaining the income fromsecurity market gameat first, and then and further on. All techniques of the technical analysis were created separately one from another and only in 70-s years have been incorporated in the unique theory with the general philosophy, axioms and the basic principles.

The technical analysis is a method of price forecasting with the consideration of market fluctuation schedules of the previous periods of time. The technical analysis is divided into:

- graphic method;
- mathematical method;
- oscillators;
- index of relative size of the prices;
- fractals;
- index of simplification of the market;
- trade of lines of balance;
- wave analysis;
- candle models;
- indicator stochastic;
- RSI indicator;
- an average index of the directed movement ADX, etc.

The fundamental analysis displays state of the economy of the country:

- indicators of economic growth (gross national product, industrial outputs and so forth);
- condition of trading balance, degree of dependence on external sources of raw materials;
- growth of monetary mass in national market;
- rate of inflation and inflationary expectations;
- level of interest rate;
- solvency of the country and trust to national currency in the world market;
- speculative operations in the currency market;
- sectorial degree of development of the world financial market, for example of securities market which competes to the currency market, etc.

Also fundamental analysis includes research of such indexes as: the stock indices, the Dow Jones index (DJI), the Standard & Poors" index (S&P), the New York stock exchange index (NYSE Index), the American stock exchange indices (AMEX), off-exchange index to a turn (NASDAQ).

Unsolved aspects of the problem. There is defined accuracy in forecasting of currency behaviour with all analyzed indicators and practical skills as well. However the joining of all indicators in a system is rather difficult task. Very often traders are usedto follow only a few indicators that reduce forecast degree.

Neural networks as new mathematical apparatus have stimulated high breakthrough in the field of analysis and forecast of the Internet market.

The positive impact of neural networks application has been considered in works of such authors as Ezhova A.A., Minaev U.N., O. Filimonov, R. Callan, Rutkovska D., S. Haykin. Having analyzed mentioned above authors it is possible to make conclusions of neural networks use principles rather approved by them in forecasting of currency behavior.

The main research. The researches and practical approbation show about rather high forecast accuracy achieved by applying this method of analysis. Mathematical complexity of the neural networks device for unskilled user isitsonly shortcoming. However, now it is updated and a large number of software on the basis of neural networks technology allows the new trader without profound knowledge of this area successfully and automatically carry out forecasts.

If to generalize existing working techniques with neural networks for the market Internet, it has such stages [6–10]:

Data collecting. Under data collecting we understand the possible largest number of statistics for chosen currency pair. The more data is provided to a network for study, especially reliability of that network will learn to do forecasts not only within the provided sample, but also outside of it than, the better forecast accuracy we get.

Network study. During network study, for increase of accuracy of forecast we have choice in several algorithms and architecturesof networks. The architectural construction of a neural network giving the smallest case of errors, is currently been approbated.

Receiving new data forecast. After a network is already taught providing sample of data, there can be executed forecast of already new set.

Therefore, as we see, considered above technique can differ only in quantity and quality of the data provided for study and the network architecture successful choice is a merit of thetechnique author and directly influences on forecastquality.

Thus, emergence of technology of neural networks brings even more increased degree of forecast reliability of Internet market. However there are a certain number of factors which influence on forecastreliability. And the trader does not need to rely only on results of neural network forecast, and as it is necessary to consider other indicators, such as exchange indices and the technical analysisindicators, for example.

Thus, we see that there is no single technique unitingthe indicators. For the similar tasks solution it is necessary tochange mathematical apparatus to neural net-

works. As it was already noted above, neural networks are not whimsical in data sample uniformity, and it means that they can join absolutely different indicators in a model, without showing requirements to their dimension. In this regard, this work offersthe updated technique of mathematical apparatus of neural networks for accuracy increasing and forecast validity.

For accuracy increase the offered forecast of this work uses complex indicator developing groups of factors of fundamental and technical analyses. For the solution of equal complexitytasks with heterogeneity of data sample and also without communication between these sets of data group, the most optimum mathematical apparatus are neural networks.

The chosen two-layer perceptron and return distribution algorithm of mistake is educational (fig. 1) and the most acceptable in this case.

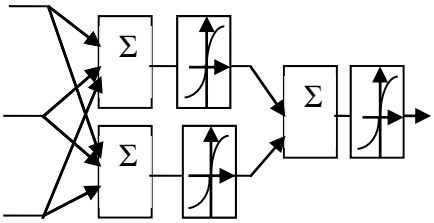

Fig. 1. Scheme two-layer perceptron

This type of neural networks is rather quite a studied and described in scientific literature and it is scrutinely considered almost in all neural networks textbooks. Each element of a network produces the weighed total of the entrances with the amendment to a composed view, and then passes this value of internal activation through functional activation and, thus, reference values of this element turn out. Elements are organized in level-by-level architecture with a direct signal transmission. Such network is easy to interpret entrance exit in which scales and threshold values are free parameters of model as nonlinear model. Such network can model functions practically at any degree of complexity, and the quantity of layers and quantity of elements in each layer define complexity of function.

Quantity definition of hidden layers and quantity of elements becomes the issue for designing. The quantity of entrance and initial elements are defined by statements of problem. Single-layered networks are considerably limited for calculation. Than quantity of layers in the networks, especially complex calculations could be done, but the excessive increase in layers can lead to excessive complexity of calculated process. To let a network process data through modeling, the scales quantity of should not exceed sample volume.

After serial calculation of linear combinations and nonlinear transformations approximation of any multidimensional function are reached at the corresponding choice of parameters of a network.

There is no feedbackin multilayered perceptron. Such models are called the networks of direct distribution. They do not own internal state and do not allow modelling development of dynamic systems without additional receptions.

Multilayered perceptron can count initial vector of *Y* for any entrance vector *X-th*, it gives value of some vector *y=f (x)* function. Therefore, the condition of any task which can be put perceptron, should be a set of vectors $\{x^1 \ldots x^s\}$ from N_I components everyone.

The set of vectors *{ y1… ys}*, each vector of y_s with yswith N^Ocomponents will be the solution of a task

$$Y^s = f(x^s),$$

where *s =1…S* – number of the shown image.

The most accepted activation functions of formal neuron are:

- rigid step;
- logistic function or sigmoid function;
- hyperbolical tangent;
- flat step;
- smoothness;
- function continuity.

As function of activation is chosen sigmoid, fig. 2 which is applied very often for multilayered perceptron and in other networks with continuous signals because it has such positive properties as:

- continuity of the first derivative that allows to learn a network gradient methods (for example, a method of return distribution of a mistake);
- quick calculation of derivative accelerates study.

$$OUT = sigm(NET) = \frac{1}{1 + e^{-NET}} .$$

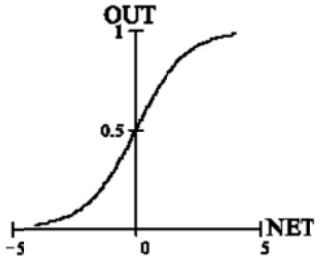

Fig. 2. Sigmoidfunctions

Creation of a neural network statistical sample from 98 data currencies which are used at a study stage of a neural network has been used. The objective to synthesize a network on the basis of multilayered perceptron will analyze entrance data and form communication between statistics of the fundamental and technical analysis (days off are given) and values at exchange rates (entrance data). The model will be used for exchange rates forecasting for future periods taking into account factors of technical and fundamental analyses.

Creation of a neural network is carried out in MS Excel with the use of the superstructure of neuroexcel.

As entrance data have been taken the main fundamental and technical indicators which possible toshow in numerical scale:

- index of the relative size of the prices *(X1)*;
- index of simplification of the market *(X2);*
- Dow Jones index (DJI) *(X3);*
- "Standard &Poors" index (S&P);
- index of the New York stock exchange (NYSE Index) *(X5);*
- indices of the American stock exchange (AMEX) *(X6);*
- index off-exchange to a turn (NASDAQ*) (X7);*
- indicator stochastic (*X8)*;
- RSI indicator (*X9*);
- average index of the directed movement ADX (*X10).*

Output data – look-ahead values of exchange rates (*X11).*

To solve this task two-layer perceptron has been synthesized on which input of fundamental and technical indicators and the forecast of initial parameter – volumes of investments behind types – is moved and produced.

The activation functions are sigmoid functions. On each stepof calculation it was carried out adjustment of weight values and threshold sensitivity by a rule

$$\Delta w_{ij} = \varepsilon(d_j^s - y_j^s)x_{ij},$$

where $d = y$; $y = OUT$; E – parameter of a step of study.

Such rule of reduction ε continually t calculation has been established as the following: ε '=ε/1.5668, where ε' – new value of studying speed.

For normal work of model before the study beginning perceptron input data were aligned and normalized by such rule:

- entrance values x

$$x' = \frac{(x - m_x)}{\sigma_x},$$

where m_x – average value x; σ_x – average quadratic deviation x.

After performance of rationing data in a range from – 4 to 4 with probability 0.99 are obtained. To obtain data in a range from 0 to 1, if to assume that the distribution law of these factors is normal, the coding is performed using such formula:

- input values y

$$y' = \frac{(x - m_y)}{\sigma_y} + 4,$$

where m_y – average value y; σ_y – average quadratic deviation y.

The error of study is calculated in a formula:

Total square-law error.

$$E = \frac{1}{2}\sum_{k=1}^{P}(d_k - y_k)^2,$$

where E – total squared error (criteria of study); P – quantity of examples in educational set; d_k – desirable size of an exit; y_k – really received output of a network; K – quantity of examples.

The simple neural network is constructed. To get rid of superfluous calculated complications at the expense of alignment of a range of variables by means of a superstructure of neuroexcel it is executed reprocessingof entrance data. The Mean/Variance option at which data turn into dimensionless form calculatingthe average and rationing their dispersion is chosen.

For determination of the input parameters importance of the Boxcounting function which defines the statistical importance of entrances for the set exits is used. We find results for the most and the least significant parameters, and also those having intermediate values. Reduction of entrances quantity allows reducing the study time of a neuronet or gives the chance to increase its nonlinear qualities. Also removals of the most non-significant entrances which value the about 0 positive, will be displayed on value of dispersion which should be possible far away from unit. The calculated relation of Average/dispersion is calculated with the use of the Boxcounting function. The larger such relation is, the better model predicts.

On all indicators satisfactory values of the calculated factors will be used for creation of neuronet model have been received.

The constructed two-layer neural network has architecture 10-3-1 (quantity of entrances - quantity of neurons in the first layer - quantity of exits) and the following parameters:

Quantity of layers without the entrance (*Number of layer*) =2.

Quantity of entrances (*Number of inputs*) =10.

Quantity of neurons in the first layer (*Layer1, neurons*) =3.

Order of nonlinearityof the first layer (*order*) =1.

Type of initial function of the first layer (*function*) = sigmoid function.

Quantity of neurons in the second layer (*neurons*) =1.

Order of nonlinearity of the second layer (*order*) =1.

Type of initial function of the second layer (*function*) = linear.

Study of a neural network. At the following stage network study begins. Nature of test sample is established to *Random* because for problems of approximation the most essential is the casual choice of a test set. Such algorithm of study is established:

- initial error of elements (*Initial delta*) =0,1;
- minimum mistake (*Minimal delta*) =1×10-8;
- maximum mistake (*Maximal delta*) =10;
- decrease step *Nu*(-) =0,5;
- increase step *Nu*(+) =1,2.

On the first step, the study has been finished, when it has reached number of 1000 eras. The error of study is 0.06 which is stabilized when the mark has reached 856 eras is received. Insignificant errors of the line of real data from data, foreseen by a network, have been

graphically received. In other words, the network gives out the same data set which no more than 1% moved on entrance with a possible mistake.

Performance of such network is described in a formula

$$OUT = sigm(\sum sigmNET) = \\ = \frac{1}{1+exp(\lambda_3\left\{\frac{1}{1+exp(\lambda_1\sum_{i=1}^{10}\sum_{j=1}^{3}x_{ij}^1 w_{ij}^1)} + \frac{1}{1+exp(\lambda_2\sum_{i=1}^{3}\sum_{j=1}^{1}x_{ij}^2 w_{ij}^2)}\right\}},$$

where i – entrance number; j – neuron number in a layer; l – layernumber.

For l=1: J=1,3; i=1,11: x_1^1 – indexof the relative size of theprices; x_2^1 – indexof simplification of themarket; x_3^1 – DowJonesindex (DJI); x_4^1 – index "Standard &poor's" (S&P)" (S&P); x_5^1 – indexof the New York stock exchange (NYSE Index); x_6^1 – indexesof the American stockexchange(AMEX); x_7^1 – index off-exchange to a turn (NASDAQ); x_8^1 – indicatorstoahastik; x_9^1 – indicator RSI; x_{10}^1 – averageindex of the directed movementADX.

For l=2:I=1,3; j=1: x_1^2 – prospective values of exchange rates.

w_{ij}^l – weight factorof entrance$i$of neuronnumber j in layer$l$, Net_{lj} – signal NET j-neuron in layer l, Out_j – entrance signal of neuron, vector of data which represents prospective values of exchange rates.

Thus, construction and calculation of economic-mathematical model of exchange rates forecasting with neural networks is executed.

Thus, construction and calculation of economic-mathematical model of forecasting of exchange rates by means of neural networks is executed.

Research conclusions and recommendations for further research. Carried out research in the methods of foresting optimization of exchange rates on the Internet market have allowed to draw such conclusions:

1. There are rather large numbers of fundamental and technical indicators which allow carrying out exchange rates behavior forecasting of Internet market.

However any of indicators cannot give high accuracy offorecast. Only complex analysis of indicators allows making a forecast with more or less high precision.

2. For increase of forecast accuracy of exchange rate in the Internet market it is necessary to createthe economic-mathematical model which would allow uniting the indicators of technical and fundamental analyses.

3. It is offered to construct economic-mathematical model of exchange rates forecasting taking into account the indicators of technical and fundamental analyses. Considering the fact that the selected group of indicators (index of the relative size of the prices, index of simplification of the market, the Dow Jones index, the "Standard & Poors", the New York stock exchange index, the indices of American stock exchange, the RSI indicator, the average index of the directed movement ADX, theoff-exchange index to a turn, the stochastic indicator) is not homogeneous by its nature, has variousdimensions, and is proved that use of mathematical apparatus of neural networks will be the most acceptable in this case.

Designing of a neural networkforecasting of exchange rates with the neural networks on the basis of multilayered perceptron is performed. As an asset function a sigmoid function is chosen. High validity of predicting properties of confirmed model with the received minimum error is received.

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Мета. Мета полягає в розробці та побудові економіко-математичної моделі прогнозу курсів валют засобами нейронних мереж для визначення поведінки курсів на Інтернет-ринку з урахуванням факторів технічного та фундаментального аналізів.

Методика. Для вирішення поставленої мети використано методи порівняльного аналізу, системного комплексного підходу та методи економіко-математичного моделювання засобами нейронних мереж.

Результати. Проведено дослідження основних факторів, за допомогою яких можна робити прогноз щодо заміни курсів валют у майбутньому. Визначено, що на поведінку курсів валют впливає достатньо велика кількість факторів, які відносяться до методів фундаментального та технічного аналізів. Встановлено, що жоден із факторів не має 100% надійності у прогнозі. Лише застосування комплексного підходу дає високу ступінь прогнозу. З метою здійснення комплексного підходу запропонована та побудована економіко-математична модель прогнозу курсів валют засобами нейронних мереж, що дозволила об'єднати показники фундаментального та технічного аналізів.

На основі показників технічного й фундаментального аналізів поведінки курсів валют на Інтернет-ринку сформована група факторі, що мають числовий вимір. Виконане обгрунтування математичного апарату нейронних мереж як оптимального для побудови економіко-математичної моделі з метою виконання прогнозів і з урахування мети, поставленої в даній роботі. На основі сформованої групи факторів виконана побудова економіко-математичної моделі прогнозу курсів валют засобами нейронних мереж, на вхід якої подаються дані за відібраними факторами, а на виході отримується прогнозне значення курсів валют.

Наукова новизна. Виконана побудова економіко-математичної моделі прогнозу курсів валют на Інтернет-ринку засобами нейронних мереж, що, на відміну від існуючих, враховує групу із десяти факторів, таких як: індекс відносного розміру цін, індекс полегшення ринку, індекс Доу-Джонса, індекс „Стендард энд пауэрз", індекс Нью-Йоркской фондової біржі, індекси Американської фондової біржі, індикатор RSI, середній індекс спрямованого руху ADX, індекс позабіржового обороту, індикатор стоахастик.

Практична значимість. Полягає в можливості підвищення точності прогнозу курсів валют на Інтернет-ринку за допомогою використання вдосконаленого математичного апарату, в основу якого покладена розширена група чинників, що впливає на зміну курсів валют.

Ключові слова: *прогнозування курсів валют, нейронні мережі, фундаментальній аналіз, технічний аналіз, Інтернет терейдінг*

Цель. Цель заключается в разработке и построении экономико-математической модели прогноза курсов валют средствами нейронных сетей для определения поведения курсов на Интернет-рынке с учетом факторов технического и фундаментального анализов.

Методика. Для решения поставленной цели использованы методы сравнительного анализа, системного комплексного подхода и методы экономико-математического моделирования средствами нейронных сетей.

Результаты. Проведено исследование основных факторов, с помощью которых можно делать прогноз относительно изменения курсов валют в будущем. Определено, что на поведение курсов валют влияет достаточно большое количество факторов, относящихся к методам фундаментального и технического анализов. Установлено, что ни один из факторов не имеет 100% надежности в прогнозе. Лишь применение комплексного подхода дает высокую степень прогноза. С целью осуществления комплексного подхода предложена и построена экономико-математическая модель прогноза курсов валют средствами нейронных сетей, которая позволила объединить показатели фундаментального и технического анализов. На основе показателей технического и фундаментального анализов поведения курсов валют на Интернет-рынке сформирована группа факторов, которые имеют числовое измерение. Выполнено обоснование математического аппарата нейронных сетей как оптимального для построения экономико-математической модели с целью выполнения прогнозов и с учетом цели, поставленной в данной работе. На основе сформированной группы факторов выполнено построение экономико-математической модели прогноза курсов валют средствами нейронных сетей, на вход которой подаются данные по отобранным факторам, а на выходе получается прогнозное значение курсов валют.

Научная новизна. Выполнено построение экономико-математической модели прогноза курсов валют на Интернет-рынке средствами нейронных

сетей, которая, в отличие от существующих, учитывает группу из десяти факторов, таких как: индекс относительного размера цен, индекс облегчения рынка, индекс Доу-Джонса, индекс „Стэндард энд пауэрз“, индекс Нью-Йоркской фондовой биржи, индексы Американской фондовой биржи, индикатор RSI, средний индекс направленного движения ADX, индекс внебиржевого оборота, индикатор стоахастик.

Практическая значимость. Состоит в возможности повышения точности прогноза курсов валют на интернет-рынке по средствам использования усовершенствованного математического аппарата, в основу которого положена расширенная группа факторов, влияющая на изменение курсов валют.

Ключевые слова: *прогнозирование курсов валют, нейронные сети, фундаментальной анализ, технический анализ, Интернет терейдинг*

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V.S. Kanev, Dr. Sci. (Tech.), Associate Professor,
Yu.V. Shevtsova, Cand. Sci. (Tech.), Associate Professor

Siberian State University of Telecommunications and Information Sciences, Novosibirsk, RF, e-mail: shevcova_yuliya@mail.ru, kanev@sibsutis.ru

POSTERIOR MODELING OF OPERATIONAL LOSSES

В.С. Канів, д-р тех. наук, канд. фіз.-мат. наук, доц.,
Ю.В. Шевцова, канд. техн. наук, доц.

Сибірський державний університет телекомунікацій та інформатики, м. Новосибірськ, РФ,
e-mail: shevcova_yuliya@mail.ru; kanev@sibsutis.ru

АПОСТЕРІОРНЕ МОДЕЛЮВАННЯ ОПЕРАЦІЙНИХ ВТРАТ

Purpose. To develop methodological approach for adaptive modeling of operational losses.

Methodology. Methods of artificial intelligence systems theory, probability theory, graph theory, probability logic, theory of decision, mathematical statistics, expert evaluation, etc. were used.

Findings. Methods of identification, evaluation, treatment and monitoring of operational risk have been generalized and systematized. The methodology for decision support system of operational risk management based on Bayesian techniques has been developed. The proposed method of Bayesian modeling of operational risk events has been tested on business processes of macro-regional telecom operators, “Siberia”, “Rostelecom”. Risk factors “data loss during the transfer to the new software or new versions of the software.”

Originality. Analytical capabilities of applying Bayesian techniques in operational risk management has been identified and formalized.

Practical value. We have developed methods for decision support system into operational risk management which can be used by companies in the total system of management.

Keywords: *operational losses, Bayesian networks, influence diagrams, modeling*

Problem setting. Recently academic and business communities have shown increasing interest in the operational risks management.

This trend is caused by several reasons. In our opinion the most important of these are:

- increasing control of market regulators regarding efficiency of the internal control and risk management;
- need to develop new methods of business processes and management;
- increasing losses in companies because of reasons which are unrelated to any direct nonfinancial and nonstrategic risks.

However, despite the relatively large number of practical application and theoretical researches operational risk management is still poorly formalized area.

The above reasons explain the relevance of our research, the aim of which is to develop technique and tool for operational risk management. In the present article it puts more emphasis on the implementation of the mechanism of operational losses in management, as it is the main goal of operational risk management.

So far, neither national nor foreign experts do not develop standard definition of the term “operational risk” [1–2]. To update this definition we have applied quite a popular in the management process approach considering risk in this application as a process having input and output parameters [1–2].

Risk as the process should be presented as causal model that includes the following components: objective sources, risk event and its effects. Let specify the nature of each component of causal model of risk in the context of operational risk:

- object of operational risk;

Objects of operational risk are internal business processes or their operations.

- operational risk events;