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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POSTERIOR MODELING OF OPERATIONAL LOSSES

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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;

Operational risk event is the event in the business process of having unregulated nature, arising under the action the sources of the business risk, which are the result of operating losses.

It should be noted that in the context of operational risk goal is realization procedures for the implementation of business process according to its reference model, and operational risk event is, respectively, the deviation of the actual procedures for implementation of the business process from the reference model. Thus, the level of operational risk characterizes the quality of business processes implement.

- sources of the event operational risk;

Sources of operational risk are the reasons that trigger realization of operational risk events on business processes. Sources of operational risk events arise from both the internal environment: system, people; and external: natural and social events.

- effects of operational risk events;

Effects of operational risk events appear in operation losses.

Summarizing the above arguments, we give the following definition of "operational risk".

Operational risk is the risk of loss caused by:

- infringement of procedure implementation rules of business processes, which can be sources of system, people, external events of non-financial nature;

- methodological inaccuracy of procedures for implementation of business processes.

Overview of recent researches. Analysis of sources [1–2] showed that the most serious methodological difficulty in operational risk management has to create adequate operational risk assessment tools. Obviously, the main drawback of qualitative methods of operational risk assessment is their subjectivity, and, consequently, possible inadequacy at the same time the initial condition for the application of quantitative methods is the availability of a representative database of operational risk incidents that in most cases is not. The combined method integrates in both empirical data and subjective expert assessments. In this regard, promising operational risk management is seen using combined methods (fig. 1).

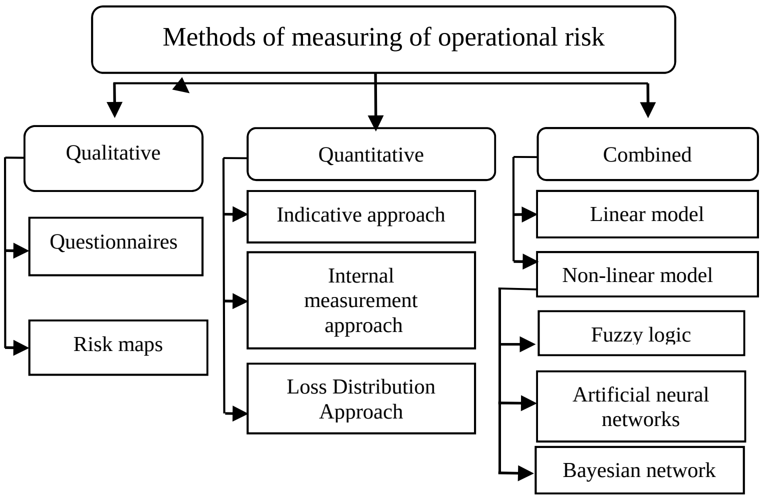

Fig. 1. Classification model of operational risk measuring methods

Hypothesis of research. In our opinion the most perspective measuring tool of operational risk is Bayesian networks (Bayesian networks, BN). This conclusion is based on the following assumptions:

- bayesian networks can combine empirical data, theoretical concepts and subjective probability estimates (and therefore sometimes called belief networks (Bayesian belief networks)). Approach based on subjective probabilities allows modeling extremely rare event and quite productive, if necessary, taking into accounting priori judgments of experts, as well as the absence of sufficient historical data;

- using Bayesian networks is represented in the form of causal relationships with substantial interpretation of each variable in terms of the considered problem, which is extremely useful when specifying causal model of operational risks;

- bayesian networks are adaptable models whose parameters can be updated with new (incomplete) information [3]. So, each time getting through the training of Bayesian networks for newly incoming information of values function of probability distribution for random variables can be carried building their recovery.

Bayesian network in operational risk management.

A Bayesian network is $N=(G,X,P)$, where:

- $G=(V,E)$ – the acyclic directed graph with random nodes $V=(v_1,\dots,v_n)$ and directed edges E, given by the ratio of conditional independence between them so that if two nodes v_i and v_j d-separated in certain evidence ε, to $P(v_i\,|\,\varepsilon)=P(v_i\,|\,v_j,\varepsilon)$;

- X – set of random variables that are representative of the nodes of the graph G;

- P – set of conditional probability distribution $P(x_v \mid x_{pa(v)})$ for each random variable $x_V \in X$ [3].

Type of Bayesian network is diagram of influence (DI) which in addition to random node also contains nodes decision and utility nodes [3].

According to the Bayesian approach, knowledge defined as a set of According to the Bayesian approach, knowledge defined as set of random variables. From our point of view, when modeling operational risk as random variables should be considered components of their causal models, namely sources (random nodes), operational risk event (random node), the effects (utility nodes) (fig. 2).

Creation of topology diagrams influence modeling of operational risk events, there is initial stage of the process of risk management – identification and should be carried out by experts with deep knowledge of the analyzed business processes with organizational, methodical and consulting support risk managers.

In order to identify possible events operational risk on specific business process need to determine what adverse events may occur when it is running. In order to identify specific sources of operational risk events it is necessary to determine its cause. In order to identify the effect of operational risk event it is necessary to determine the losses which it may hold.

The next stage of the risk management process – measuring of their level – is defining priori conditional probability distributions for the variables representing the operational risk event $(P(ORE = k \mid S_1 = l,...,S_n = s), k,l,s = 0,1)$ and the sources of it $(P(S_i = l), l = 0,1; i = \overrightarrow{1,n})$, as well as average effect, i.e. the operational losses $(L(E_j \mid ORE = 1), j = \overrightarrow{1,m})$ (fig. 2). (Here and below, the following abbreviations apply: *ORE* – operational risk event; *S* – source; *E* – effect; *EL* – expected (operational) losses; *A* – act, corrective action; *C* – cost, costs of resource).

These parameters can be estimated as expert (based on priori experience) and on the basis of formal analysis (reliability theory, the theory of queuing, etc.).

Specifying causal model of operational risk events in the form of influence diagrams to determine the expected value of operating losses

$$EL = \sum_j L(E_j \mid ORE = 1) \times P(ORE = 1), j = \overrightarrow{1,m},$$

$$P(ORE = 1) = \sum_{l,s} P(ORE = 1 \mid S_1 = l, \ldots, S_n = s) \times$$
$$\times P(S_1 = l) \times \ldots \times P(S_n = s), l, s = 0,1.$$

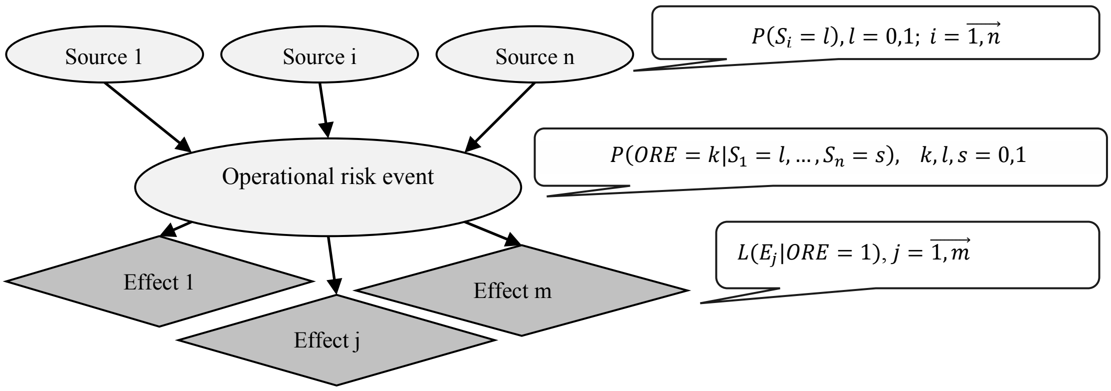

Fig. 2. Influence diagram modeling of operational risk event

The use of Bayesian inference in influence diagram allows us ranking the sources of operational risk events influence degree on the estimated operating losses in order to identify the most critical of them

$$EL(|S_i = 1) = \sum_j L(E_j \mid ORE = 1) \times$$
$$\times P(ORE = 1|S_i = 1), j = \overrightarrow{1,m}; \forall i = \overrightarrow{1,n};$$
$$P(ORE = 1|S_i = 1) =$$
$$= \sum_{l,p,r,s} P(ORE = 1|S_1 = l, \ldots, S_i = 1, \ldots, S_n = s) \times$$
$$\times P(S_1 = l) \times \ldots \times P(S_{i-1} = p) \times P(S_{i+1} = r) \times \ldots$$
$$\times P(S_n = s), \qquad l, p, r, s = 0,1; i = \overrightarrow{1,n}. \qquad (1)$$

Also influence diagrams allow you forming a "reverse" analysis – determining the probability that the event of operating losses (realization of operational risk events) occurred as result of exposure to particular source

$$P(S_i = 1|ORE = 1) =$$
$$= \frac{\sum_{l,s} P(ORE = 1|S_1 = l, \ldots, S_i = 1, \ldots, S_n = s) \times}{P(ORE = 1)}$$
$$\frac{\times P(S_1 = l) \times \ldots \times P(S_i = 1) \times \ldots \times P(S_n = s)}{P(ORE = 1)};$$
$$l, s = 0,1; \forall i = \overrightarrow{1,n}. \qquad (2)$$

Comparing the formula (1) and (2) it is easy to determine the role of particular source of operational risk events in terms of its influence degree on the value of the expected operating losses.

To do this, the probability of the operational risk events in conditional specific source ($P(ORE = 1|S_i = 1)$, formula (1)) depends directly on the probability of this source($P(S_i = 1)$); or probability of specific source of operational risk event($P(S_i = 1|ORE = 1)$, formula (2)) depends on probability of the operational risk event (P ($P(ORE = 1)$)

$$P(ORE = 1|S_i = 1) \times P(S_i = 1) = \\ = P(S_i = 1|ORE = 1) \times P(ORE = 1) = \\ = P(ORE = 1, S_i = 1) = \\ = P(S_i = 1, ORE = 1), \forall i = \overrightarrow{1,n}.$$

Thus, classification simplifying the quantitative rank of sources of operational risk events degree influence on the estimated operating losses in order to identify the most critical of them accumulate the joint probability of the operational risk events and this source

$$r_i = \frac{P(S_i = 1, ORE = 1)}{\sum_i P(S_i = 1, ORE = 1)}, \forall i = \overrightarrow{1,n}.$$

Advantage of Bayesian techniques, distinguishing them from many models of operational risk measuring, is the possibility of specification of priori network parameters on the basis of incoming posteriori information about them using procedure called in Bayesian terminology adaptation.

We see several directions of application for this property BN and ID.

First of all, it is obvious that the problem of estimating priori distribution of the variables DI modeling of operational risk event is quite complex in terms of the possibility of getting professional advice from experts. In addition, value judgment can in a certain degree be inadequate. Adaptation parameters DI on incoming information will allow (eventually) them to get closer to their objective values.

Second, the adaptation procedure allows DI modeling operational risk event to implement the mechanism update distribution probabilities of its variables on the basis of new information on cases of realization of operational risk events and/or sources of their incurred. It is important to note that this information may be even incomplete.

Adaptation procedure BN or DI involves approximation of the states probability distribution of each variable by Dirichlet distribution, which can be explained by the fact that the Dirichlet distribution is the conjugate prior of the multinomial (polynomial) distribution, which can be approximated by the distribution of any type [3].

Let us consider variable X and fixed configuration π of states for the parents of X. For this configuration, we need to specify probability distribution over the states of X. Instead of hard probabilities of these states, we give density for the probabilities in the form of Dirichlet distribution. If X has n states, we need n parameters: $\alpha_1, \ldots, \alpha_n$ to specify the Dirichlet distribution. Let θ_i denote the probability of state x_i given parent configuration π. Assuming Dirichlet distribution, the joint density has the form

$$P(\theta_1, \ldots, \theta_n) \propto \prod_i \theta_i^{\alpha_i - 1};$$

$$\sum_i \theta_i = 1; \; 0 \le \theta_i \le 1; \; i = \overrightarrow{1,n}.$$

Adaptation procedure involves the calculation of the posterior probability distribution over the state of variables on condition evidence $P(\theta_i|\varepsilon)$ which is regarded as mixture of $n + 1$ Dirichlet distributions: one for the set of cases where the parent configuration is different from π, and one for each of the n cases where $X = x_i$ and the parent configuration is π

$$P(\theta_i|\varepsilon) = \mathcal{D}ir[\alpha_1, \ldots, \alpha_n]\big(1 - P(\pi|\varepsilon)\big) + \\ + \sum_i \mathcal{D}ir[\alpha_1, \ldots, \alpha_i + 1, \ldots, \alpha_n] P(x_i, \pi|\varepsilon); \; i = \overrightarrow{1,n}.$$

The final stage of the risk management is procedure. Purpose of procedure of operational risk – optimize the expected value of operation losses to acceptable level for the company through the implementation of correction actions that affect the sources of operational risk events.

To determine the economic efficiency of activity in the influence diagram modeling operational risk event (fig. 1) is necessary to add decision node representing the act, and the utility node reflecting the cost of its implementation ($C(|A_i = 1), i = \overrightarrow{1,n}$), as well as to correct priori probability distribution of the variable corresponding to the source of operational risk events over which it manages ($P(S_i = l \mid A_i = g), l, g = 0,1; i = \overrightarrow{1,n}$) (fig. 3).

Economic efficiency activities determined by the ratio of reduction the feasible operating losses (as result of its implementation) and the cost of its implementation

$$E_{A_i} = \frac{EL(|A_i = 0) - EL(|A_i = 1)}{C(|A_i = 1)}; \; i = \overrightarrow{1,n};$$

$$EL(|A_i = g) = \sum_j L(E_j \,|ORE = 1) \times \\ \times P(ORE = 1|A_i = g);$$

$$g = 0,1; \;\; i = \overrightarrow{1,n}; \; j = \overrightarrow{1,m};$$

$$P(ORE = 1|A_i = g) =$$

$$= \sum_{l,p,s} P(ORE = 1|S_1 = l, \ldots, S_n = s) \times$$
$$\times P(S_1 = l) \times \ldots \times P(S_i = p|A_i = g) \times \ldots \times$$
$$\times P(S_n = s), l, p, s = 0{,}1; i = \overrightarrow{1,n}.$$

Thus, using Bayesian techniques to create system of identification, assessment and procedure of operational risk contributing to solution of numerous methodological problems of operational risk management.

Application. The proposed methodology of Bayesian modeling of operational risk events was tested on business processes of Macro regional telecommunication operator –"Siberia" MRF and "Rostelecom" JSC.

Fig. 4 shows the fragment of business process model "Information system installation". Thus business process is characterized by risk event "Data loss during the transfer to new software or new versions of software" in the transmission test of commercial operation.

The experts of the Department of Information Systems in "Siberia" MRF had identified elements of the possible risk and estimated the probability and cost parameters of the Bayesian model.

So, the following risk factors were identified within "Data loss during the transition to the new software or new versions of software":

- operator or program error when transferring data;
- software design defect in data transfer;

and effects:

- penalties and claim payments due to loss or distortions of data;
- disconnections in customer service.

Currently developed software product allows to model problem using Bayesian techniques. Among them the best known are: Bayesware discoverer, Hugin, Netica. The present research used the program Hugin Lite (www.hugin.com).

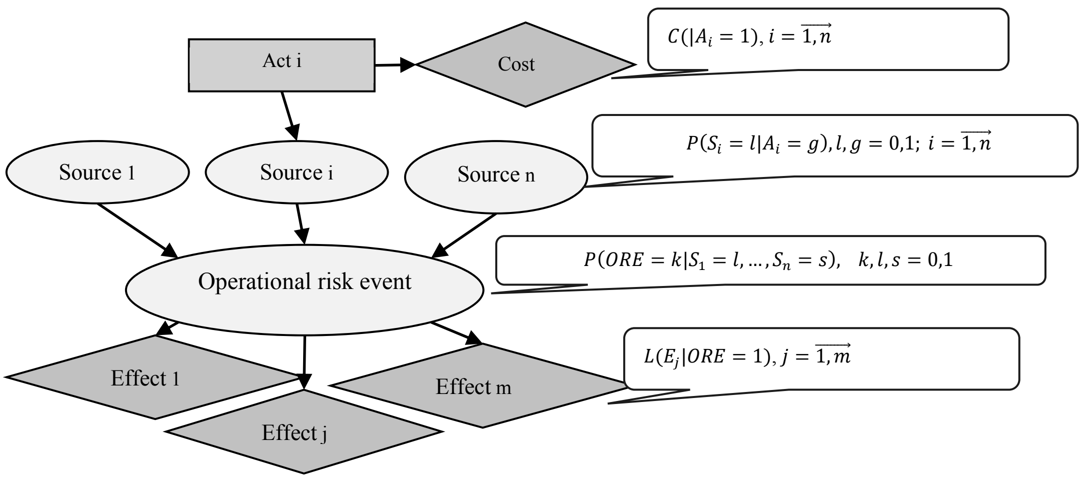

Fig. 3. Influence diagram modeling the situation of treatment of operational risk event

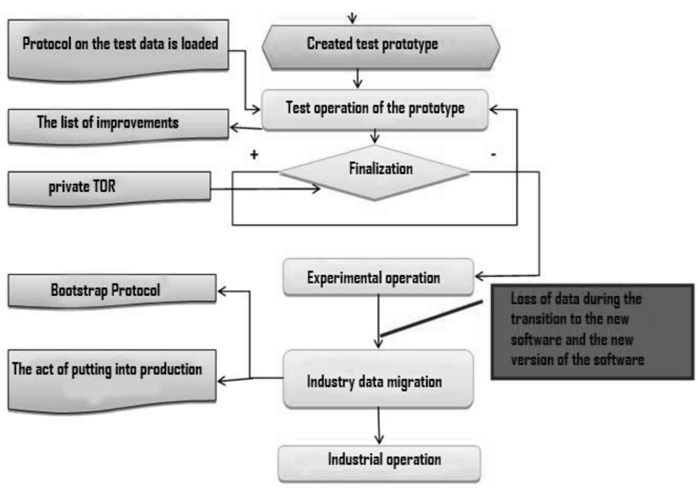

Fig. 4. Fragment of business process "Installation information system"

Conclusion. So, Bayesian technology in contrast of traditional statistical methods to measure operational losses allow to present operational risk as system, so it can be seen not only as a way of modeling operational losses, but also as complex management tool that provides widely analytical capabilities. Thus the use of Bayesian techniques for modeling operational risk is the essential step in improving the methodological level of operational risk management.

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Мета. Розробка методичного підходу адаптивного моделирования операційних втрат.

Методика. Застосовуються методи теорії штучних інтелектуальних систем, теорії ймовірностей, теорії графів, імовірнісної логіки, теорії прийняття рішень, математичної статистики, експертного оцінювання та ін.

Результати. Досліджений методичний підхід адаптивного моделювання операційних втрат. Пропонована методика байєсівского моделювання подій операційного ризику апробована на бізнес-процесах макрорегіонального оператора зв'язку – МРФ „Сибір“ ВАТ „Ростелеком“. Виявлені чинники ризику „Втрати даних при переході на нове ПЗ або нові версії ПЗ“.

Узагальнені та систематизовані методичний та модельно-вимірювальний апарати процедур ідентифікації, оцінки, обробки та моніторингу операційного ризику. Розроблений методичний супровід системи інтелектуальної підтримки прийняття рішень з управління операційним ризиком на основі байєсівських технологій.

Наукова новизна. Виявлені й формалізовані аналітичні можливості застосування байєсівських технологій при управлінні операційним ризиком.

Практична значимість. Основний прикладний результат дослідження полягає в розробці модельно-методичного комплексу підтримки прийняття рішень з управління операційними втратами, що може застосовуватися компаніями в загальній системі їх управління.

Ключові слова: *операційний ризик, втрати, байєсівські мережі, діаграми впливу, моделювання*

Цель. Разработка методического подхода адаптивного моделирования операционных потерь.

Методика. Применяются методы теории искусственных интеллектуальных систем, теории вероятностей, теории графов, вероятностной логики, теории принятия решений, математической статистики, экспертного оценивания и др.

Результаты. Исследован методический подход адаптивного моделирования операционных потерь. Предлагаемая методика байесовского моделирования событий операционного риска апробирована на бизнес-процессах макрорегионального оператора связи – МРФ „Сибирь“ ОАО „Ростелеком“. Выявлены факторы риска „Потери данных при переходе на новое ПО или новые версии ПО“.

Обобщены и систематизированы методический и модельно-измерительный аппараты процедур идентификации, оценки, обработки и мониторинга операционного риска. Разработано методическое сопровождение системы интеллектуальной поддержки принятия решений по управлению операционным риском на основе байесовских технологий.

Научная новизна. Выявлены и формализованы аналитические возможности применения байесовских технологий при управлении операционным риском.

Практическая значимость. Основной прикладной результат исследования состоит в разработке модельно-методического комплекса поддержки принятия решений по управлению операционными потерями, который может применяться компаниями в общей системе их управления.

Ключевые слова: *операционный риск, потери, байесовские сети, диаграммы влияния, моделирование*

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