The Use of Fuzzy Cognitive Modelling to Manage Information Security Audit of Information Portals of Regional Executive Authorities

M Yu Rytov¹, E V Leksikov¹, V I Sakalo² and P A Kovalev¹

¹ Department of Information Security Systems, Bryansk State Technical University, Bryansk, Russia
² Department of Mechanics, Dynamics and Strength of Machines, Bryansk State Technical University, Bryansk, Russia

E-mail: rmy@tu-bryansk.ru

Abstract. At the moment the domestic policy of the Russian Federation is being formed in difficult conditions of a foreign policy situation. The regional policy is built on the platform of alignment of social and economic development indices. To maintain the activity of regional social and economic systems is important for the management system of executive authorities (EA), including regional ones. To ensure feasibility of public administration, it is necessary to have vitally active social and economic systems.

1. Introduction
An important role in management of regional social and economic systems is played by information portals which act as management information systems (MIS). These systems allow quickly to collect, store, transmit, analyse and handle information of the changing situation for making decisions [1].

Development of MIS imposes new requirements to process management methodology, taking into account changes in the situation. The analysis of information streams of regional EA shows that for making management decisions, only 10-15% of the available information are used today [2].

Providing regional EA with a uniform access point to information, production and economic resources allows to optimize and automate the process of management decision-making. However, to provide and implement an information portal in such an extensive and complex area is not an instantaneous and easy process. The information portal is an integral part of improving the management decision-making for state bodies and executive authorities, which is designed to solve the critical problems of information processes. Also, it should be noted that, the process of developing information portals of regional authorities is not typified at the moment and does not allow different regions to create information portals quickly on the basis of standard design solutions with the aim of rapid exchange and processing data.

Regional EA need information portals which have the following roles:

Information portal = IMS + AIS

Figure 1. The functional role of IP.
Here, AIS (automated information system) is a system intended for storing, searching and handling information and appropriate institutional resources; IMS (information management system) is a uniform set of interconnected elements for collecting, handling, storing and providing information on the activity of regional EA for making management decisions.

Development of an information portal of regional executive authorities is a complex process. Before developing information portals, there is performed long and large-scale work on collecting primary requirements, their analysis and design of future software, assessment of threats and risks. All in all, this time-consuming process is called an information security audit [3].

For convenience, the first design stage can be divided into 4 levels, each level is carried out in a strict sequence. The description of each level is given below:

- the 1st level - IS audit implementation.
- the 2nd level – RS preparation. At level 2 requirements specification of AIS development (RS competition) is formed. It contains various types of primary requirements for AIS.
- the 3rd level – IT type choice. At the third level, the basic engineering solution of RS objective is chosen.
- the 4th level – project issue and risk prediction. Eventually, a preliminary design of specified AIS should be made.

Let us consider the first level of IS audit.

The first level includes realization of IP necessity and search of primary information on the required subject. There are also formed primary requirements for the information portal, and the list of the purposes and tasks, which it will have to carry out.

Then, on the basis of primary requirements, it is necessary to carry out an information security audit (IS audit). An IS audit is defined as an audit which covers study and assessment of all aspects (or one of them) of automated information processing systems, including connected manual processes and the interface, which combines them.

An IS audit is an activity intended for collecting and assessing a number of proofs to define if the information system is safe, maintaining the integrity of posted and processed data, allowing reaching strategic tasks and using information resources effectively.

Active development of information technologies promoted the beginning and the subsequent improvement of audit methodologies with using computers and componentry. Information technologies are applicable at all stages of carrying out the audit today: during planning, implementation, documenting the auditor works, recording the auditor conclusion. Therefore, the problem of audit automation is very important at the moment.

Nowadays, it is rather difficult to imagine an auditor without the use of information technologies. On the one hand, the computer is a universal remedy which is intended to help auditors to solve various types of daily problems. These problems include acceleration of getting and processing the information from client’s database, processing the information received by auditors (information service); development of analytical spreadsheets, audit applications, a more rapid audit (methodological service). Solving other problems embraces opportunities of editing texts and spreadsheets, database development and others. However, on the other hand, AIS used by clients imposes special requirements on research arrangement and choice of auditing procedures. These factors complicate the process.

At present, organizations need a structured approach to audit and management of information technologies. The analysis shows that existing approaches to carrying out the IS audit do not take into account mutual influence of IT processes on each other which is explained by existing restrictions on the total input.

The control system of IT processes of an organization is a complex organizational and technical composition, since the mechanism of managing its elements is semi-structured, allowing formalization generally at the qualitative level where changing system parameters can lead to hard predictable changes in its structure [4].
Therefore, to solve the tasks of information analysis with such fuzziness, fuzzy models have gained special currency. These models are based on the theory of fuzzy sets representing generalization and reconsideration of major directions of classical mathematics. For formalization of these complex systems, the method of fuzzy modeling is most often used particularly for semi-structured systems. The method of fuzzy modeling is based on the concept of fuzzy sets.

At the heart of fuzzy modelling, there is a concept of a fuzzy cognitive card (FCC) defined by B. Kosko. By means of the fuzzy cognitive card, the information on a system or a process is represented as a set of significant factors (concepts) and their cause-effect relations. Besides, the junctions of the derived fuzzy graph represent fuzzy sets and the directed edges define the extent of influence (weight) of the connected concepts that, in comparison with other methods, gives the opportunity to formalize numerically intangible factors and to use incomplete fuzzy information [5].

Cognitive cards have the following attributes:

- the influence relations between concepts are presented by fuzzy sets;
- to solve the problem of accumulative influence of several input concepts on one output concept and to define the mediated influence of concepts on each other, we used the interval method with operations on intervals of the fuzzy set of a-levels which represent the concept condition and their influence on each other;
- the system characteristics of the fuzzy cognitive card are defined on the basis of a transitively closed matrix of interferences which elements represent fuzzy sets assigned in codomains of positive and negative values of basic sets;
- calculation of the system parameters representing the fuzzy sets or singletons (a fuzzy set which contains exactly one element) modified as a result of transformations is realized on the basis of the interval method with operations on intervals of the fuzzy set of a-levels;
- the uncertainty of the used system characteristics is considered in the carried-out analysis.

Application of fuzzy cognitive modeling methods on the basis of FCC statistical analysis allows one to solve the problem of assessment of process stability to ensure the demanded level of information security due to the research of influence coherence of various IT processes of an organization and identification of the steadiest outlines to achieve business goals and ensure their safety [6].

The general procedure of using FCC-apparatus to solve the problem of assessment of IT strategy security at this stage of planning provides realization of the following final set of stages which are assigned by a standard way of FCC development [6].

**Stage 1. Input of concept sets**

Step 1-4. Generation of concept sets which characterize various parameters.

For FCC modeling, it is necessary to assign concept sets which will define the further structure of a fuzzy cognitive model of the process which we need to study. This research studies an IT audit of an enterprise before IP developing.

In this case, we take sets of threats, risks, IT goals, levels of IT process capabilities, as well as key indicators of IT process efficiency [5].

Each set of concepts has the following view:

\[
K^Y = (K_1^Y, K_2^Y, ..., K_I^Y),
\]

(1)

where \(K_i^Y\) - the concept characterizing the level of threat influence on security (\(i = 1, ..., I\)).

All other concept sets are assigned in the same way.

Step 5. Generation of a cognitive model of the studied process.

Steps 1-4 result in developing the structure of a fuzzy cognitive model:

\[
K = (\alpha_1 \times K^Y, \alpha_2 \times K^b, \alpha_3 \times K^{KPI}),
\]

(2)

International Conference on Information Technologies in Business and Industry 2016

IOP Conf. Series: Journal of Physics: Conf. Series 803(2017) 012131
doi:10.1088/1742-6596/803/1/012131
where \( \alpha_1, \alpha_2, \alpha_3 \) are binary functions defining the list of main business goals, IT goals and IT processes for a particular profile of the organization;
\( K^a, K^b, K^{KP} \) are concept sets which were assigned in steps 2-4.

**Stage 2. Generation of influence relations between sets**

Step 1-4. Generation of influence relations between concepts of all input sets at stage 1.

Let us consider set \( K^y \) as an example. The influence relations between concepts of set \( K^y \) are presented in the form of weights \( w_{ij}^y \in [-1,1] \) and considered as elements of fuzzy adjacency matrix \( W^{BI} \).

\[
W^{TP} = \begin{bmatrix}
w_{11}^y & w_{12}^y & \cdots & w_{1i}^y \\
w_{21}^y & w_{22}^y & \cdots & w_{2i}^y \\
\vdots & \vdots & \ddots & \vdots \\
w_{ji}^y & w_{j2}^y & \cdots & w_{jj}^y 
\end{bmatrix}
\]

(3)

These relations displayed in the form of directed graph edges representing fuzzy cause-effect relations between concepts can be positive, negative or neutral, and characterize the corresponding influence of concepts on each other.

Step 5. From the definition of concept interference in initial fuzzy adjacency matrix \( W \) with positive and negative fuzzy relations, it is necessary to pass to a fuzzy matrix of positive relations \( V \) with size \( 2I \times 2I \) which elements are defined from matrix \( W \) with size \( I \times I \), using the way of the following replacement:

\[
\begin{align*}
\text{if } w_{ij} > c w_{ij} > c, & \quad v_{2i-1,2j-1} = w_{ij}, v_{2i,2j} = w_{ij} \\
\text{if } w_{ij} < c w_{ij} < c, & \quad v_{2i-1,2j-1} = -w_{ij}, v_{2i,2j} = -w_{ij}
\end{align*}
\]

The rest of the elements have zero values.

In the case of ambivalence in the initial matrix, the positive and negative couple of influence weights will be transformed according to the similar algorithm, only certain values are put on the diagonals instead of zeros.

Step 6. The coordinated relations of concept interferences are defined as a result of transitive closure \( V \):

\[
V = V^2 V^3 \ldots V^n
\]

(4)

where degrees of fuzzy matrixes are calculated on the basis of operation of the max-T-composition.

After that, the result is presented in the form of a modified matrix consisting of positive and negative weight couples \( W = \| w_{ij}, w_{ij} \| \) received in the following way:

\[
\begin{align*}
w_{ij} &= \max (v_{2i-1,2j-1}, v_{2i,2j}) \\
w_{ij} &= -\max (v_{2i-1,2j-1}, v_{2i,2j})
\end{align*}
\]

(5)

The result of stage 2 is a fuzzy cognitive card displaying system factors of the analyzed system (process, problem).

**Stage 3. Generation of fuzzy models**
The models are formed in terms of influence of one concept on another, for example, in the case of the IS audit, it is possible to develop a fuzzy cognitive model of threat influences, risk influences on IT processes and business goals of regional EA.

As a result, we get fuzzy cognitive models which contain all key parameters, as well as the influence of each parameter on each others. Thus, it is possible to receive a full picture and to weigh all pluses and minuses when planning to develop the software solution.

2. Conclusion
In this paper, we suggest a method to manage the auditing procedure of EA information security on the basis of the method of fuzzy modelling and developing fuzzy cognitive cards. This method allows one to input an unlimited number of concept sets into the model, and then to model the influence of these concepts on each other under the influence of various factors.

Thus, this method of carrying out the IS audit can play an important role for regional EA where introduction of an information portal is planned, since its use can help to find out the dependence between estimated threats, risks and business goals and IT capabilities of the information portal.

References
[1] Rytov M Yu and Kovalyov P A 2015 BGTU Bulletin 1(45) 95-100
[2] Review of the COBIT standard (Control Objectives for Information and related Technology) v 4.1 Methodology, processes, criteria, introduction of Cobit [An electronic resource], the Electronic magazine IT Expert 2012 the access Mode: <http://www.itexpert.ru/ru/biblio/cobit/>
[3] Maximov V I and Kornoushenko E K 1999 Analytical bases of application of cognitive approach at the decision semistructured problems Works YIP of the Russian Academy of Sciences
[4] Risk monitoring based on fuzzy cognitive models [An electronic resource], the International magazine "Software Products and Systems" 2007 the access Mode: http://www.swsys.ru/index.php?id=399&page=artilce
[5] Rytov M Yu and Leksikov E V 2014 Information and security 17(2) 276-279
[6] Averchenkov V I, Ritov M Yu, Kuvyklin A V and Rudanovsky M V 2007 Audit of information security of executive bodies 100
[7] Averchenkov V I, Ritov M Yu and Gaynulin T R 2008 Protection of personal data in the organization 124