COGNITIVE APPROACH TO THE DEVELOPMENT OF DESISION SUPPORT SYSTEMS FOR EMERGENCIES IN EDUCATIONAL INSTITUTIONS

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ABSTRACT

The methods of developing decision support systems for localization, mitigation and possible elimination of emergencies consequences (terroristic assaults, accidents, explosions, fires, etc.) that are possible in educational institutions are discussed in the article. Fuzzy cognitive maps are discussed as the basis for the development of decision support systems for emergencies. Such systems application features and methods of learning for management development models are studied in the article. The use of management models enables carrying early recognition of a possibility of an emergency occurrence on the base of vague and inconsistent information, as well as allows predicting the most probable scenario of its development. A decision support system allows generating of emergency elimination plans real-time by using available force, measures and resources optimally. Implementation of the system of support of managerial decisions is considered by the example of fire safety of educational institutions. In the framework of the cognitive approach the basic factors (concepts) that define the state of fire safety have been identified and their causal and investigative links have been established. On this basis, built a cognitive model of fire safety and proven its stability. With its help, using pulse simulation explored scenarios of changes in condition of fire security under the action of destabilizing and control actions. Proved the efficiency of application of cognitive technologies for optimal management strategies of fire safety and reduce fire risks. Cognitive modeling allows predicting the effectiveness of management decisions. The proposed modeling approach for fire safety applicable to public buildings for any purpose.

Keywords: educational institutions, fire safety, cognitive maps, decision support system.

1. INTRODUCTION

Security issues significantly affect the stability of the educational sector. Educational institutions are required to ensure safety of students, faculty and staff when provide educational services. Educational institutions (EI) are a high risk establishment, since they are objects with large concentrations of people, objects with a lot of tangible property, objects storing chemical, biological, explosive or flammable substances.

Security problems solving for educational institutions is of particular importance in the modern conditions. It is explained by:

- attractiveness of educational institutions for terrorists, owing to a significant damage when implementing a threat;
- buildings and structures features as high risk objects, each of which represents a complex architectural and building structure with a large engineering infrastructure;
- presence of a significant number of people in buildings with a limited possibility of escape and rescue when there is an emergency.

The tendency to increasing number and scale of emergencies is retained in the educational system.
This is related to the objective reasons and an unsatisfactory state of security systems in educational institutions. World average annual increase of emergencies: on the number of victims - 4%; for property damage - more than of 10%.

Therefore, problem of a security from emergencies of different nature remains relevant for students, teachers and staff.

It is required to adopt new methods and approaches.

Emergencies generally develop rapidly, and are accompanied by material and human losses, so it is important to take prompt and proper decisions on dealing with emergencies and mitigation and elimination of emergencies consequences [1-5].

It makes it very difficult, since decision-making process takes place under time pressure, incomplete and inaccurate information requires consideration of many aspects like technical, organizational, psychological and other.

An important direction to increase efficiency and quality of management measures for the prevention and elimination of emergencies in educational institutions is developing decision support systems.

The base for development of such systems is mathematical models of dynamic processes of emergency events comprising formalized elements operating in an uncertain environment.

The challenge of emergency modeling related to the fact that a character of each hazardous situation is individual and takes place in conditions of uncertainty when neither scale of the disaster is unknown, nor the complexity of the rescue measures, nor amount of necessary force and means. Efficient allocation of limited resources between different areas of recovery measures also remains a complex issue.

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In case of emergency or critical event at educational institutions an efficiency of elimination efforts of the emergency depends on proper organization of recovery measures management, which essentially are: collecting situational data, analysis and assessment of the situation, preparation of conclusions and proposals for recovery actions; making (specifying) decisions and bringing problems to the executors, organizing of cooperation and comprehensive support of rescuers meas.
A typical feature of a course of emergencies is uncertainty, vagueness and authenticity of data about parameters of an emergency. In these cases, it is advisable to use management models based on a fuzzy logic, in particular, fuzzy cognitive maps (FCM) [6-8].

A fuzzy cognitive map is called the causal chain:

$$G = (C, W), \tag{1}$$

where C - the set of concepts; W-set of relationships between concepts.

$$\omega(c_i, c_j) \in W \to [-1;1] \tag{2}$$

At vertices of a directed graph, corresponding to an emergency, events or key elements are located. Directed arcs represent causal relationships between them and determine the degree of influence (weight) of these relationships. At the same time, parameters of events and extents of their mutual influence can be expressed by both precise quantitative measures and fuzzy qualitative relations [9-12].

Using FCM for a modeling of emergencies course and emergencies liquidation simplifies the analysis of ongoing processes and causal relationships between situation concepts. A pre-designed fuzzy cognitive map allows predicting a type and parameters of a scenario, which will take place on a course of an emergency with initial parameters partially and inaccurately specified.

Experts estimate weights of causal relationships between concepts on the following scale when building a cognitive map: "strong influence" - (+1); "influence" - (+0.5); "no influence" - (0); "negative influence" - (-0.5); "very negative impact" - (-1).

In the case when values of causal relationships weights extract from data while learning, weights can take arbitrary fuzzy values from the set [-1; 1]. Matrices of concept's mutual interference are built on the base of existing fuzzy cognitive map, and then the existing map behavior and stability are studied.

System indicators of a fuzzy cognitive map are calculated such as consonance and dissonance of concept's mutual interference, which calculation based on a comparison of profiles derived from the map concepts based on matching, balance, and influence power criteria. The main advantage of fuzzy cognitive maps application is the ability to estimate a concept's mutual interference quantitatively.

Fuzzy cognitive maps application allows modeling an uncertainty in relationships between events and decisions which being made.

One of the most dangerous risk factor by the nature of damaging factors and possible effects is a fire in educational institutions.

2. COGNITIVE MODEL OF THE FIRE SAFETY

The system of fire safety (FS) of educational institution is characterized by several tens indicators which cover its building blocks and factors influencing its state [13]. Large number of these indicators, indistinct, qualitative, and sometimes and the contradictory nature of their interrelations, the lack of exact quantitative information strongly complicates assessment of fire-prevention security of EI and complicate the choice of the most effective actions for its improvement in conditions of rigid temporary and financial restrictions. In this regard it is reasonable to look for the solution of the specified tasks on the basis of cognitive model of the FS system [14].

The first stage of creation of such model is identification and quantitative assessment of major factors (concepts) defining the condition of the FS system. By results of the analysis of expert information the following list of concepts was agreed:

C1 - the level of work of the head and the responsible persons designated by it on ensuring fire safety;
C2 - the condition of electro technical and other potentially fire-dangerous equipment;
C3 - conditions of keeping, storages and uses of fire and explosion hazardous and combustible materials;
C4 - the mode of performance of fire-dangerous works;
C5 - the level of proficiency and responsibility of personnel of EI and students;
C6 - the condition of material and technical resources of fire safety (system of the fire alarm system, the notification, emergency firefighting equipment, evacuation ways and exits)
C7 - completeness of performance of actions for providing FS according to notes and instructions of the state fire supervision (SFS);
C8 - external fire-dangerous influences (arsons, lightning discharges and other natural disasters);
C9 - degree of compliance of EI to requirements of fire safety.

As the numerical characteristic of degree of compliance of EI to requirements of FS, i.e. the variable of the state X9(0∈; 1) the target concept of C9 the share of structural divisions of EI (EI) conforming to requirements of FS found by results of work of the fire and technical commission can be accepted.

Factors of C1 and C7 belong to managing concepts. As quantitative criterion of X1 – the level of work of the head and administration of EI on prevention of the fires, it is possible to take the share of the available documents and the executed actions from total quantity of the documents and actions which are subject to execution. The quantitative index of X7 of completeness of correction of violations of requirements of the FS revealed by SFS is the share of the executed notes and instructions. The condition of the destabilizing factors of C1, C2 and C3 is described by the X1, X2, X3 variables representing shares of the equipment, the rooms and hot work which are not conforming to obligatory requirements of FS. The numerical characteristic of X8 of external fire-dangerous influence of C8 is its statistical probability. Values of variables of the condition of concepts Xi, i = 1, 2... 9 can be established by processing of documents SFS, results of the examinations conducted by the fire and technical commission, expert polls, statistical data and other materials.

The second stage of creation of cognitive model of system of fire safety of EI is definition of the direction (sign) and force of the cause and effect relations between each couple of factors [15-17]. The linguistic estimates of these relations found by results of the analysis of expert information were displayed on the interval [-1; 1] in the form of numerical values (scales) of communications between factors (Figure-1).

The cognitive model of the FS system can be visually presented in the form of the oriented weighed graph - the indistinct cognitive map. Tops of the graph - the factors defining FS, and arches - the cause and effect relations (Figure-1) between it.

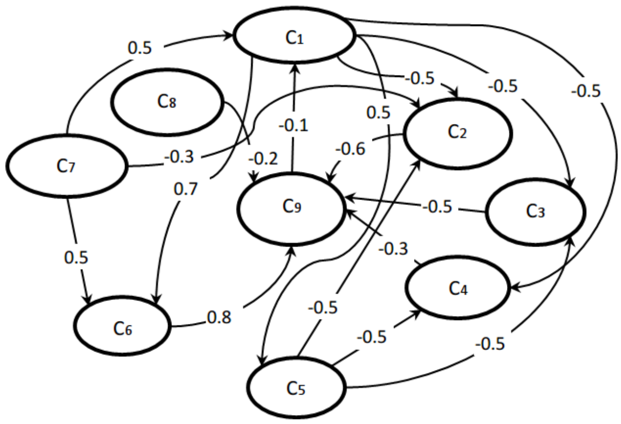

Figure-1. Indistinct cognitive map of system of fire safety.

The card reflects negative impact on the condition of FS of the destabilizing factors of C2, C3, C4 and C8, positive influence of managing directors of C1, C7 and the stabilizing factors of C5 and C6, and also negative back coupling between degree of compliance of EI to requirements of FS and level of work of the persons responsible for fire-prevention prevention – improvement of the condition of FS quite often results in self-complacency and weakening of control of observance of fire-prevention requirements.

The weight of arches of the cognitive map form the connectivity matrix of its tops of $W = \|w_{ij}\|$ where the element of the matrix w_{ij} defines influence of the concept of C_i on the concept of C_j (Table-1).

Table-1. Connectivity matrix of tops of the cognitive map.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	**0**	**- 0,5**	**- 0,5**	**- 0,5**	**0,5**	**0,7**	**0**	**0**	**0**
C2	0	0	0	0	0	0	0	0	- 0,6
C3	0	0	0	0	0	0	0	0	- 0,8
C4	0	0	0	0	0	0	0	0	- 0,3
C5	0	- 0,5	- 0,5	- 0,5	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0,8
C7	0,5	- 0,3	0	0	0	0,5	0	0	0
C8	0	0	0	0	0	0	0	0	- 0,2
C9	- 0,1	0	0	0	0	0	0	0	0

The cognitive model of the FS system is the instrument of studying of the mechanism of interaction of the factors influencing its state, means of the research of possible scenarios of development of this state and the basis for development of the administrative decisions directed to improvement of fire-prevention security of OU. For the solution of these tasks the cognitive model has to be steady in relation to the local influences leading to changes of variables of the condition of factors [18-23].

The analysis of stability of cognitive models is based on the research of roots of period equation of the connectivity matrix:

$$\det(W - \lambda E) = 0, \tag{3}$$

where λ - the complex variable, E - the unit matrix. The cognitive model is steady if modules of all roots of characteristic equation there is less unit:

$$|\lambda_i| < 1, \quad i = 1,2,...k, \tag{4}$$

where k – the connectivity matrix order equal to number of concepts of model.

The computer program by means of which it is shown that stability condition (4) for cognitive model of the FS system is satisfied (modules of eigen values of the matrix of communications is developed for implementation of cognitive modeling: 0.89; 0.89; 0.63; 0.63; 0; 0; 0; 0).

Let's consider pulse modeling of possible scenarios of change of the condition of the FS system as a result of the destabilizing and managing influences. The initial condition of the FS system describes the vector

$$X(0) = (x_1(0), x_2(0), \dots, x_9(0)), \tag{5}$$

where $xi(0)$ - initial values of variables of the condition of concepts. Changing variable conditions of concepts, we create the initial vector of impulses

$$p(0) = (p_1(0), p_2(0), \dots, p_9(0)), \tag{6}$$

where $p_i(0) = \Delta x_i / x_i(0)$ - the relative increments of variables of the state set in shares of unit or percent. As all factors of the FS system are interconnected, change at least of one of them calls the cascade of changes of all other factors. Pulse process which is described by the following iterative ratio is so initiated:

$$p_i(n+1) = \sum_{j=1}^{k-1} w_{ij} p_j(n) \tag{7}$$

where n = 0, 1, 2 … - ordinal value of iteration to which there corresponds the n-th step of modeling. As a result of performance of some number N of steps of modeling pulse process meets to the stationary vector of increments:

$$P(N) = (p_1(N), p_2(N), \dots, p_k(N)), \tag{8}$$

defining the new condition of the FS system which describes the vector

$$X(N) = (x_1(N), x_2(N), \dots, x_k(N)) \tag{9}$$

where $x_i(N) = x_i(0) \cdot (1 + p_i(N)), \quad i = 1,2,\dots,k$.

3. RESULTS AND DISCUSSIONS

By means of pulse modeling it is possible to compare influence of separate factors and their combinations on the condition of FS of educational institution. Compliance of the step of modeling to the certain temporary interval is established by practical consideration.

Let's consider, for example, the initial condition of the FS system corresponding to the vector

$$X(0) = (0{,}7;\ 0{,}1;\ 0{,}05;\ 0{,}08;\ 0{,}7;\ 0{,}8;\ 0{,}7;\ 0{,}03;\ 0{,}8) \tag{10}$$

Let's assume that as a result of easing of attention to prevention of the fires the number of violations of FS increased ($p2(0)$ = 0,03; $p3(0)$ = 0,05; $p4(0)$ = 0,05;), the level of proficiency and responsibility of personnel decreased ($p5$ =-0,05), and other factors remained at the previous level. As a result of these changes after 10 steps of modeling we will receive the established vector of the increment of variable concepts (Figure-3):

$$P(10) = (0{,}001;\ 0{,}05;\ -0{,}07;\ 0{,}07;\ -0{,}05;\ 0{,}07;\ 0;\ 0;\ -0{,}10), \tag{11}$$

which defines the new condition of the FS system. This state was much worse initial: the destabilizing factors amplified, and the indicator of compliance of EI to requirements of FS went down for 10%. For correction of the arisen situation the following managing influences were undertaken: level of work of the head and the persons responsible for FS was increased for 20% ($r1$ = 0, 2), and execution of notes and instructions of SFS is improved for 15% ($r7$ = 0, 15), indicators of all other factors are left without changes. After 15 steps of modeling the FS system was returned in the initial state (Figure-3) generally due to significant improvement of material and technical resources of FS (growth by 13%) and decrease in number of violations when using electric equipment (-6%). At the same time implementation of rules of fire prevention regime when using flammable materials and when carrying out hot work is recovered only partially, and assessment of level of proficiency of personnel decreases that is explained by more strict approach to its assessment.

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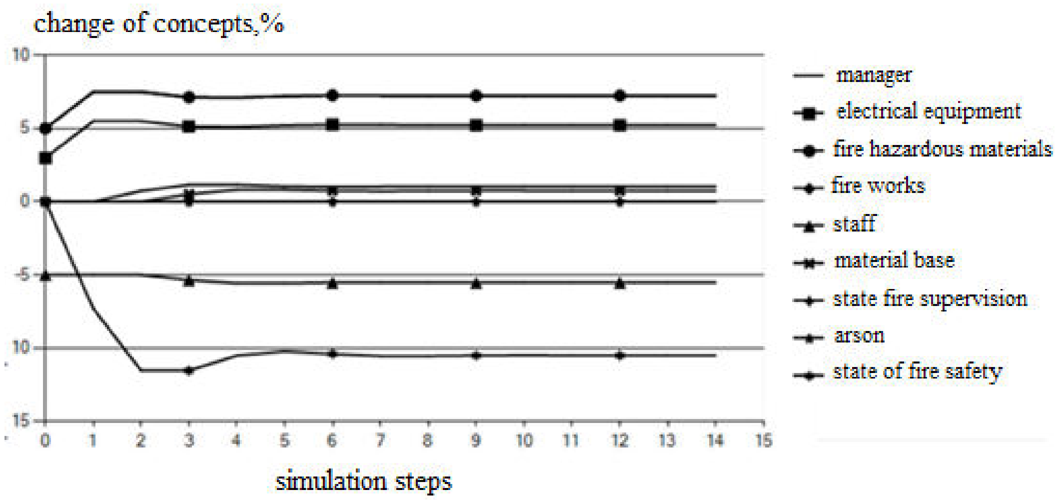

Figure-2. Modeling of change of the condition of fire safety of educational institution as a result of the destabilizing influences.

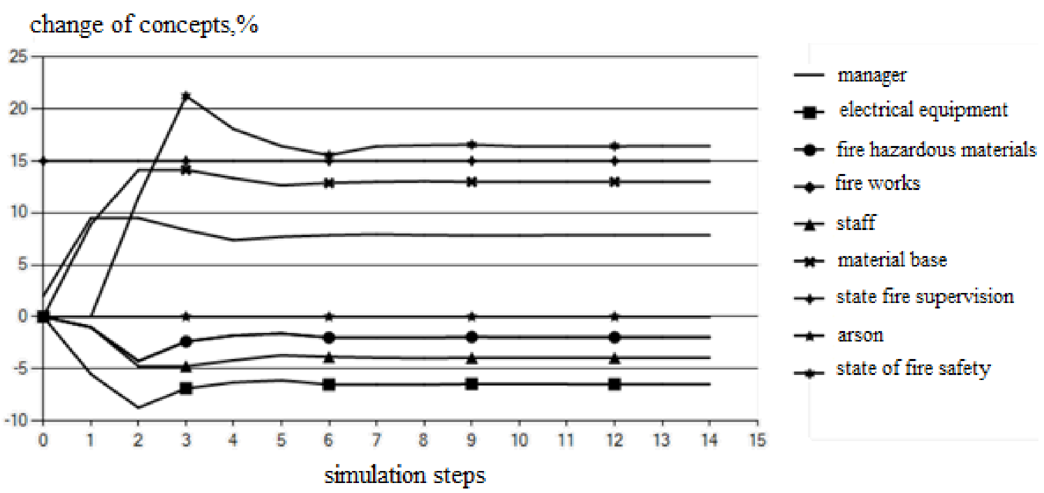

Figure-3. Modeling of change of the condition of fire safety of educational institution as a result of managing influences.

Let's note that the quantitative assessments received as a result of modeling are indicative as they depend on the connectivity matrix which is the product of processing of subjective expert knowledge. Verification of its cognitive model, i.e. comparison of results of modeling with the available experimental data is necessary for increase in reliability of the analysis of the state and tendencies of development of the FS system. Following the results of verification correction of model which can include changes of structure of concepts and communications between them, and also specification of force of these communications is carried out [23, 24].

4. CONCLUSIONS

The cognitive analysis allows to find out the mechanism of formation of the condition of the security system of educational institution, and also to investigate scenarios of development of this state as a result of the destabilizing and managing influences. The cognitive model of system of fire safety is the effective remedy of support of adoption of the administrative decisions directed to increase in compliance of educational institutions to requirements of fire safety.

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