Annals of Warsaw University of Life Sciences – SGGW
Agriculture No 63 (Agricultural and Forest Engineering) 2014: 97–104
(Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 63, 2014)

The model of strategic management of organizational and technical systems, taking into account risk-based cognitive approach

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Abstract: *The model of strategic management of organizational and technical systems, taking into account risk-based cognitive approach*. Main questions of developing a strategic model of organizational and technical systems in the terms of risk are considered in the paper. The authors propose a model of risk management based on fuzzy cognitive map. This model enables strategic decision-making, taking into account the influence of external and internal environment factors of the OTS.

Key words: organizational and technical (technological) systems (OTS), strategic management, risk, cognitive map, fuzzy cognitive map

INTRODUCTION

Develop strategies for managing organizational and technical (technological) systems (OTS) is impossible without taking into account the uncertainties and risks. Possible uncertainty regarding the following parameters: objective functions OTS, the set of admissible strategies, the initial state of OTS, certain forecasts (for example, prices), the parameters of cost functions and others.

In today's unstable environment, the internal environment of the system do not allow for prediction of the future state of the system with high accuracy. Very important in the strategic management of OTS is the consideration of risks, risk events, risk management, methods of prevention of risk events. Therefore, it is reasonable to develop information about technology risk assessment, risk management, risk prevention.

Strategic management OTS directed primarily at solving complex task, which aims to increase the effectiveness of OTS as a whole. Solving this problem is possible by developing a comprehensive strategic management OTS method, taking into account risk based on constructing fuzzy cognitive models of risk management. The purpose of the article is to develop a risk management model based on fuzzy cognitive maps which will enable strategic decision-making with regard to the impact of factors external and internal environments.

MATERIAL AND METHODS

Dynamics functioning OTS requires a clear definition of goals, a set of actions and decisions, fair distribution of resources, adaptation to the external environment and internal coordination. The

developed strategies are implemented, taking into account the current state of OTS, but may not always be the way it is intended. Therefore necessary to continually adapt the strategy, leading it into line with current requirements of the external environment and current status of OTS, even though at the beginning it was developed with consideration of external and internal factors. With an optimal strategy, they affect entire OTS, OTS capabilities and its environment.

OTS strategic management should ensure selection decisions in each present moment in order to achieve this goal in the future, based on the fact that both environmental and operating conditions of the system will vary. However, in most cases, is difficult to predict how these changes will occur. So the question is particularly acute for making strategic decisions in a rapidly growing uncertainty and risk factors that have a decisive impact on future results.

On this important to the study of the conditions and causes of risk events, development of measures to reduce the probability of risk, avoidance of risk or cost reduction as a result of risk. That is important for risk management, especially in the development strategy of OTS.

The risk is called the characteristic of the system (the effects of management decisions etc.), operating under uncertainty described by a set of events, the probability of this event and the loss function. Sometimes risk is called the expected of loss, and the level of security – the difference between the maximum and expected loss [PMBOK guide 2000, Ermacova 2005, Novykov 2005].

Investigation of risk management, analysis and consideration of the factors that cause them, the definition of possible losses, development of measures to prevent the occurrence of risk events is an important task in the strategic management of OTS.

Risks generated by various environmental factors and internal state of the system. Therefore, in general, the risks of OTS strategy can be divided as follows:

1. Internal risk factors are generated by internal state of the system and which include:
   – production risks associated with the onset of problematic situations during the process OTS;
   – financial risks associated with financial transactions in OTS;
   – investment risks, characterized by the potential impairment of the investment portfolio of OTS;
2. External risks are generated by environmental factors of:
   – market risks related to changes in market conditions in the environment;
   – political risks associated with changes in the political situation in the environment;
   – form major risks that are difficult to predict.

During the study on risk management using various models and methods, which are characterized by the presence and completeness of the original information. Depending on the completeness of the original information risk situations can be divided into three groups:

– the situations with sufficient statistical data to determine the law of distribution of probabilities (including checks necessary statistical hypotheses) occurrence of risk events;

– the situation of insufficient statistical data to determine the law of distribution of probability of risk events;
– the situation of lack of statistical information on the possibility of risk events.

Decisions regarding the future strategy most commonly adopted in the absence of information. Existing management practices, such as the so-called method of decision tree, method of payment matrix, and various game models [Silov 1995, Borisov et al. 2012], have the possibility of decision making in situations where there may be significantly and statistical evaluation of the consequences of decisions, namely, in full awareness. Therefore, they can not be used in the presence of a third type of risk situations. There is a need to reduce the use of uncertainty and risk in the strategic management of OTS expert information that will provide opportunities estimation using ordinal scale ranks the emergence of risk management, the impact of risk factors on the different nature of the targets, and identify the most important risk factors.

Generalizing technology and incorporation of risk analysis involves the following two steps. In the first phase we solve the problem of synthesis of optimal control mechanism. If no uncertain factors (deterministic model), then there is no need for risk management. If the present model uncertain factors, it can be obtained parametric solution synthesis. If the uncertain parameter will be known at the time of decision making, it is possible to directly use parametric solutions. Otherwise, there are two options.

One approach might be to eliminate uncertainty and deterministic solution of the problem, namely the calculation of the worst case, the expected benefits etc. This risk management is to analyze the dependence of the optimal solution from the information available about the uncertain parameter.

Another approach to risk management is to study the dependence of the optimal solution values of the uncertain parameters and the search for solutions, optimal within the available data on the possible values of uncertain parameters. Examples are: the sensitivity (stability) of the decision by the parameters of the model, using solutions that have a guaranteed maximum efficiency in a given range of values of indefinite parameters, and the application of generalized solutions – parametric family of solutions of the problem of governance, which is a parameter of the loss in efficiency, depending on range of values of model parameters in which this solution is effective [Prokopenko and Chernova 2013].

There are two main classes of mechanisms for risk management. The first class of mechanisms – mechanisms aimed at reducing the risk of adverse and emergency situations. This class of mechanisms include external and internal economic mechanisms to reduce risk: incentives, taxation, quotas, reservations and more. The second class of mechanisms – mechanisms of redistribution of risk (insurance), aimed primarily not at risk reduction, and its redistribution and reduce the negative effects of the occurrence of adverse events.

Simulation scenario objectives OTS is determining the following tasks:
– identify achievements in this situation the goal;
– study changes over time consumption;

– assess the impact of environmental factors and internal condition of the efficiency of the system.

The model is a dynamic model of network type, which enables to simulate the consequences of strategic decisions.

Building a dynamic structural model of the system is formalized description of the trajectory of the system by obtaining intermediate states of the system and control actions that consistently puts the system from the initial state to the final, according to the goals of the system.

During the formalization of the decision-making process necessary to obtain an expression which takes into account all the signs of a problem situation, in which the target associated with the means to achieve it. Therefore, it is reasonable comprehensive study of strategic management with regard to OTS risk-based cognitive approach. Using a cognitive approach in the short term will provide an opportunity to develop and justify the strategy of OTS considering the influence of environmental factors and internal state of the system.

Strategic decision making under uncertainty and risks is carried out in several stages:

1. Identifying the most significant risk – environmental factors and internal state of the system;
2. Determination of the initial set of effective measures to reduce the likelihood of risky situations and minimize their impact;
3. Modeling of possible scenarios with regard to OTS risk;
4. Choosing an effective scenario objectives OTS recorded under risk.

In the first phase it is appropriate to use an approach based on the notion of cognitive maps and called cognitive modeling [Chen 1995]. Formally, the cognitive map – a directed graph, edges (and, to be perhaps the top) which put in line weight. It is given by the adjacency matrix:

$$W = [w_{ij}]_{n \times n} \quad (1)$$

where:
n – number of vertices;
w_{ij} – the weight of edge (i, j);
$w_{ij} = 0$ means that the edge (i, j) is absent [Carvalho and Tome 1999, Liu and Zhang 2003].

To solve the problem of bad quality defined parameters more appropriate approach is proposed by B. Kosko [1986], which introduced a fuzzy cognitive map (FCM). In general, the FCM – a weighted directed graph with set of vertices C and a set of edges E, where vertices represent factors and edges – connections between factors that are interpreted as causal relations [Sawaragi et al. 1986, Dickerson and Kosko 1998].

In order to apply formal methods of data and relevant information technology in the strategic management of OTS with regard to the risks necessary to solve the previous problem, which consists of the following steps:

– form factors of the environment and the internal state of the system that contribute to the occurrence of external and internal risks for each strategic decisions and establish links between them;
– parameterization of the obtained factors and relationships, that is a description of acceptable range of values is generally qualitative and fuzzy;
– selecting a model that is characterized by type of functions that determine

the impact of communications on the factors and methods of calculation.

Construct in a generalized form of fuzzy cognitive map risk management in determining the scenario objectives OTS [Pelaez and Bowles 1996]. Top cognitive maps correspond factors (concepts) setting (Fig. 1):

– sources of risk situations in the external and internal environment OTS, that external factors ($3\Phi_1$, …, $3\Phi_n$) and internal environment ($B\Phi_1$, …, $B\Phi_m$);
– risks posed by certain factors that affect the implementation of a strategic decision ($R_{3\Phi 1}, R_{B\Phi 1}, \ldots, R_{3\Phi n}, R_{B\Phi m}$) – indicators predicting the emergence and development of risk situations;
– corollary rate of occurrence of risk situations for OTS (P_{1i}, P_{1j}, P_{nj}, P_{mi});
– measures that are necessary to prevent or reduce various types of risks ($M_{P3\Phi 1}, M_{PB\Phi 1}, M_{P3\Phi n}, M_{PB\Phi m}$,);
– the performance of the system (P_{E1}, ..., P_{E4}).

Oriented edges define the causal relations between the factors that characterize their mutual influence on each other. Scales characterizing the power of influence factors. In this case, in order to characterize the impact force between nodes (concepts) are introduced weight $w_{ij} \in W$, characterizing the impact of a concept to one another using linguistic values scale type (very small, small, medium, large, extra large) [Zhang et al. 1989].

Besides effects may be direct or indirect [Zhang et al. 1988]. The direct influence of adjacent vertices is called impact. It is given by the elements of the adjacency matrix. Indirect effects *i* on *j* – this effect through the path of length greater than 1, which runs from *i* to *j*. The total influence is the resulting impact on all paths from *i* to *j*.

To determine the heights of cognitive maps and data relationships force method of peer review can not be used [Lega et al. 2010].

Indirect effects *i* to *j* through the path *P* going from *i* to *j* is defined by [Kosko 1986]:

$$I_P = \min_{k,l \in E(P)} w_{kl} \quad (2)$$

where:
$E(P)$ – the set of edges and path;
Pw_{kl} – weight of edge (k, l) in the path P, which is expressed in terms of linguistic variables.

The combined effect T_{ij} of *i* to *j* is defined by [Kosko 1986]:

$$T_{ij} = \max_{I_P} I_P \quad (2)$$

where the maximum is taken over all paths $P(i, j)$ from *i* to *j*. Thus, the operation I_P selects the weakest link in the path *P*, and operation T_{ij} selects the strongest of the indirect effects of I_P [Zack 1999, Kuznecov et al. 2006].

Edges (Fig. 1) reflect the strength of influence of environmental factors on the one hand and the internal factors of the system on the other hand the occurrence of risk situations. The onset of risk events cause certain effects, which in turn affect soybean values of system efficiency.

To identify effective preventive measures is consistent inclusion in the model corresponding nodes – concepts ($M_{P3\Phi 1}$, $M_{PB\Phi 1}, \ldots, M_{P3\Phi n}, M_{PB\Phi m}$). For the constructed fuzzy cognitive maps determine the degree of the complex (including in-

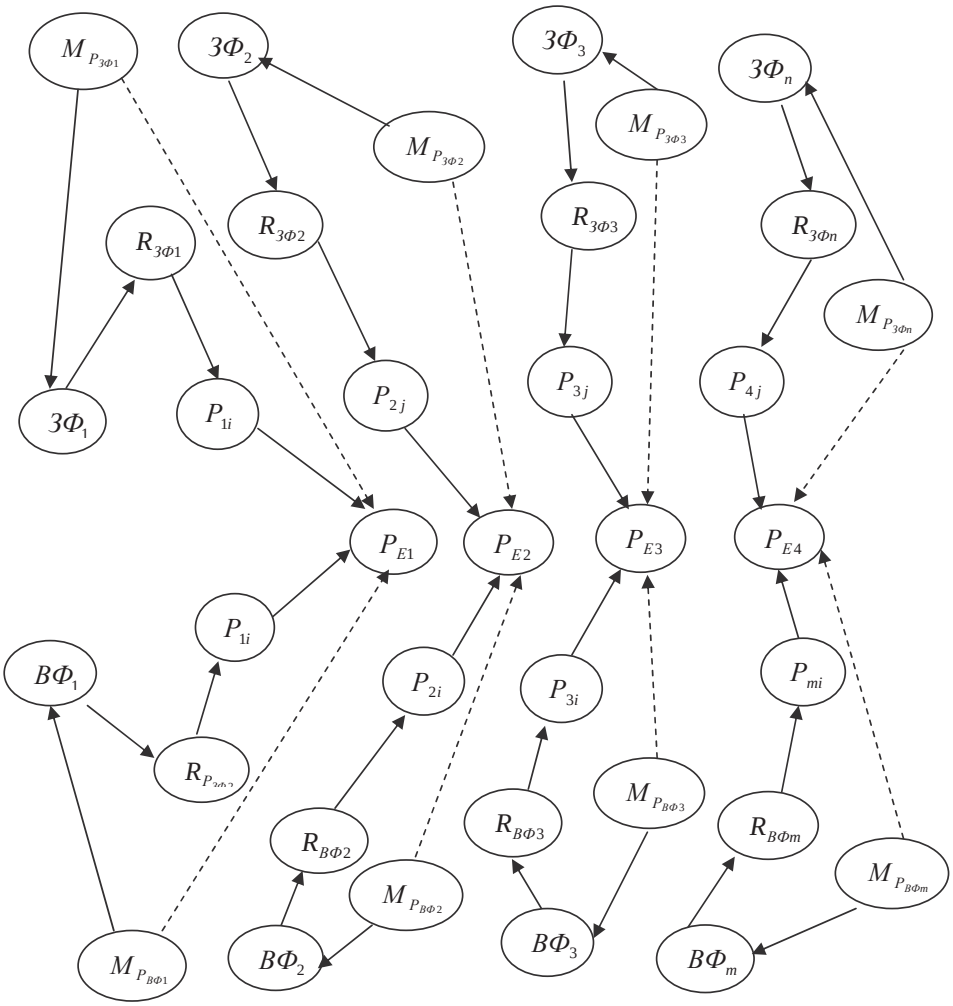

FIGURE 1. Generalized fuzzy cognitive maps of risk management in determining the scenario objectives OTS

direct) impact of the performance prediction of risk situations, and choose those activities that provide the lowest cost major impact on the level of risk and its possible consequences.

In the monitoring of risk management performed assessment of the likelihood of risk and estimated aggregate value of risk as a convolution of fuzzy appraisal of *i*-th hazardous event and the magnitude of damage from this event. For each range of values of risk $P_{3Ф1}$, which may, for example, respond acceptable, acceptable and unacceptable level of risk chosen effective primary and backup activities that have the greatest impact on the probability of risk.

When functioning OTS values of all concepts constructed fuzzy cognitive maps change, which inevitably leads to

a change in the indicators of risk. In this case, getting the data values in a pre-set intervals determines the feasibility of implementing appropriate measures to reduce risk or adverse consequences.

RESULTS AND DISCUSSION

Thus, the authors developed a generalized fuzzy cognitive model of the external and internal environment OTS as fuzzy cognitive maps (or based fuzzy cognitive graph), which is characterized by the presence of nodes (concepts) that reflect the sources of risk situations in the external and internal environment OTS and nodes reflecting the risk management measures.

CONCLUSIONS

1. Organizational and technical (technological) systems combine both organizational and technical (technological) systems and relate to complex systems. They are characterized by properties such as multidimensionality, complexity and variability patterns, availability and change many purposes, the activity is not determinism and others [Boljšakov 2006]. According to the properties of the example can be considered OTS technological complex sugar company.
2. During the due diligence evaluation problems of sugar industry by the authors were used graphic-analytical models – graphs, prographs [Ladašok and Prokopenko 2003]. However, these simulation tools are too cumbersome. So when should submit studied the problem in a dynamic structural model that consists of a set of heterogeneous objects, it is appropriate to use fuzzy cognitive maps.
3. The model of risk management based on fuzzy cognitive maps makes it possible to identify the sources of risk events in the external and internal environment of the system, the degree of their impact on system performance and to identify measures to avoid risks. This model is used in the development of alternative scenarios to achieve the objectives of OTS, which enables selection of the most efficient scenario achievement recorded by OTS risks.

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Streszczenie: *Model strategicznego zarządzania systemami organizacyjnymi i technicznymi z uwzględnieniem poznawczego podejścia na bazie analizy ryzyka*. W artykule przedstawiono podstawowe problemy dotyczące opracowania strategicznego modelu zarządzania ryzykiem opartego na poznawczej mapie logiki rozmytej. Opracowany model umożliwia podejmowanie strategicznych decyzji na podstawie wpływu zewnętrznych i wewnętrznych czynników środowiska OTS.

MS. received February 2014

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