Decision support in complex organizational systems using neural network technologies

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Abstract. In complex organizational systems in which there is asymmetry of information, an important element of effective work is equal access to objective statistics. Because of the benefits to one of the parties in such systems, key elements of effective management and making the right decisions, it is necessary to develop independent approaches. The developed approach makes it possible to assess risks in various situations and with various interactions within the system, and also allows you to recreate the missing information for decision-making from open statistical databases. The key element of the developed approach is the use of self-organizing Kohonen neural networks, which make it possible to classify objects based on the reconstructed information. The importance of the correct grouping of system objects makes it possible to recommend a management decision with greater accuracy. The developed approach allows you to reduce uncertainty (risk), and, as a result, reduce losses and maximize profits.

1. Introduction
Making the right management decisions is an important component of the successful development of a particular person, a small enterprise, a large organization or a system as a whole. The adoption of such decisions allows to ensure competent rational management and reduce risks. An important element for decision-making should be reliance on mechanisms based on objective data, which in turn should be verified by comparative, correlation, statistical, experimental, numerical, simulation or other types of analysis [1-4].

With the development of information technologies, neural network technologies are increasingly used to support decision-making [5-7]. Artificial intelligence has found application in many industries, be it: economics, medicine, transport, architecture and construction, agriculture, etc. [8-17].

2. Theoretical analysis
One of the basic principles of the development of modern society is openness. However, there are still industries for which the conditions for normal competition are not met, since one of the parties may have more information to make the right management decisions. This imbalance may be due to accumulated work experience, the level of qualifications and competencies of key decision makers, knowledge of the specifics of the product, or other features. Among the principles of a complex organizational system, the following are distinguished: the degree of organization, the complexity of the organization, purposefulness and openness. I would like to pay special attention to the latter, which characterizes the system's ability to interact with the external environment in order to exchange information. Asymmetry of information can lead to market failure in a particular area, as there is a
shift in the optimal price of a product or service. In this regard, the party that owns more information receives a significant share of the profit at the expense of less risk, and the other party suffers losses due to the lack of similar access to information, which may ultimately lead to bankruptcy or refusal to interact with a specific product or service.

Figure 1 shows the structure of a complex organizational system, which focuses on the elements that arise in the process of interaction when information asymmetry exists. These elements make it possible to level the incompleteness of data arising in the course of unequal access to statistical information. Also, such an element of control as the state is separately highlighted, which can act as a regulator for industries that are critical for ensuring its normal functioning.

![Figure 1. The structure of a complex organizational system.](image)

The importance of these elements is due to the need to exchange information between the objects of the organizational system. Figure 2 shows a diagram of the operation of the algorithm for forming an organization's management strategy and risk management.

![Figure 2. Scheme of the algorithm for the formation of an organization management strategy and risk management.](image)
One of the important components in the above scheme is the clustering of objects. To overcome uncertainty in individual areas, it is necessary to correctly identify groups of similar objects, which will allow identifying their unique characteristics. In the scientific literature, three methods of object classification are traditionally distinguished: hierarchical, faceted, descriptor. However, in recent years, neural network technologies have been increasingly used in the study and clustering of objects. One way to reduce uncertainty and reduce information asymmetry is self-organizing Kohonen maps, which is an unsupervised learning model designed for applications where it is important to maintain a topology between input and output spaces.

Figure 3 shows the structure of the Kohonen map, on which the input and output levels are present. It is also worth noting that all input neurons are connected to all neurons in the output layer.

![Figure 3. The structure of the neural network of a self-organizing Kohonen map.](image)

In this network, neurons learn on their own, without anyone's control, since competition is at the heart of the network and learning. Only vectors are fed into the input, which make up the training sample. The activation of a neuron is calculated as the distance between its weight vector \( W \) and the input pattern \( X \). Distance can be defined as dot product or Euclidean distance. Two training rules may apply: Winner-Take-All (WTA) where only the winner's weights change, or Winner-Take-Most (WTM). Then there is a change in the weights of all neurons in the neighborhood, but this change depends on the distance between the winner and the neuron in the neighborhood. In this case, the network is called a self-organizing map.

For a better understanding of the functioning of a complex system, the article [18] contains a diagram of use cases that allows you to visually display the functional requirements characteristic of the subject area. In our case, "actor" is an operator, an external database, MatLab and a database. Variants of use are represented by three modules: (1) a module for generating a random variable - it is necessary to restore information necessary for further work; (2) transformation module - it is necessary for finding eigenvectors, eigenvalues and information processing; (3) forecasting module - allows you to carry out various types of analyzes, on the basis of which the decision-maker can adjust the further processing of information, highlight critical values.

3. ** Practical significance**

The work [19] shows the possibility of simulating the results of a complex system in terms of the dependence of the results on random factors. Due to the fact that the result describes several objects of a complex system at once, it is a random vector with correlated components.

To make the right decision in the considered insurance problem for the system as a whole, it is important to assess the total risk of the system. As shown in [19], in this case, it is essential to take into account the correlation of the components of the considered random vector. However, in addition to making a decision for the system as a whole, the problem of making decisions for individual objects of a complex system is considered. In [20], the distribution function of individual losses was constructed, which has the form:
\[ F_X(x) = \begin{cases} 
0, & x < 0, \\
0.75 + \left(0.5 - \Phi\left(\frac{10\sqrt{5}x}{P\cdot S\cdot \sigma U\sqrt{6}}\right)\right) \cdot \Phi\left(\frac{a}{\sqrt{V^2 + 2a^2 + a^4}}\right) + 0.5\Phi\left(\frac{10\sqrt{5}x}{P\cdot S\cdot \sigma U\sqrt{6}}\right), & x \geq 0.
\end{cases} \]  

(1)

where \( \Phi(x) \) is the Laplace function, \( P \) is the price of one unit of the product, \( S \) is the volume of production, \( V \) and \( \sigma U \) are the coefficient of variation and standard deviation, respectively, of a random variable characterizing the result of the functioning of the system object. Figure 4 shows the graph of the distribution function of individual losses with the following parameters: \( P = 1 \) thousand rubles, \( S = 1000 \) ha, \( \sigma U = 5.25 \) 100kg/ha, \( V = 0.2904 \). The parameter values correspond to the yield of oats in the Bashmakovsky district of the Penza region.

Distribution function (1) essentially depends on the parameters \( V \) and \( \sigma U \), which characterize the objects of a complex system. When considering all objects of the system as a whole and developing an optimal solution for the entire system as a whole, as shown in [19], for some of the individual components of the system, an increase in the result is observed, for a part - the preservation of the result, and for a number of objects there is a decrease in the result. As it seems to the authors, this fact is determined by the inconsistency of the assessment of the total risk of the entire system as a whole with the risk, which is determined by the distribution function of individual losses (1).

Figure 4. The distribution function of individual damage when insuring oats.

To resolve the contradiction, the objects of a complex system are divided into groups with similar parameters of the distribution of production efficiency.

The use of simulation modeling in [19, 20] showed that one of the key issues of effective risk management by participants in the organizational system is the correct assessment of their condition. For partitioning into groups, neural network technologies, in particular self-organizing Kohonen maps [21-23], can be reasonably used. Depending on the definition of the organization to a particular cluster, an appropriate management decision is selected based on a mathematical model.

For the districts of the Penza region, a Kohonen map was built, which is shown in Figure 5.
Figure 5. Map of Kohonen for the districts of the Penza region.

The construction of the map made it possible to distinguish three clusters, which can be conventionally called "high", "medium" and "low" with, respectively, high, medium and low production efficiency. Table 1 shows the resulting division into groups. Figure 6 shows the territorial distribution of the selected groups across the territory of the Penza region.

Table 1. Distribution of districts of the Penza region by clusters based on the results of constructing Kohonen maps for oats.

| Cluster  | Districts of the Penza region                                      |
|----------|-------------------------------------------------------------------|
| high     | Bashmakovsky, Vadinsky, Issinsky, Narovchatsky, Penza             |
| middle   | Bekovsky, Belinsky, Bessonovsky, Gorodishchensky, Zemetchinsky, Mokshansky, Nizhnelomovsky, Nikolsky, Pachelmsky, Serdobsky, Tamalinsky, Shemyshesisky |
| low      | Kamensky, Lopatinsky, Kameshkirsy, Kolyshleisky, Kuznetsky, Luninsky, M. Serdobinsky, Neverkinsky, Sosnovoborsky, Spassky |

Figure 6. Distribution of groups on the territory of the Penza region (white - "medium", gray - "high", brown - "low").
In each selected group, the parameters of function (1) for the objects of the group differ little from each other, and the final risk result is determined by the controlled production parameters ($S$ and $P$).

The allocation of clusters allows us to consider each group of system objects separately, focusing on the statistical characteristics of production efficiency for the selection of optimal control strategies. The article [20] developed a procedure for choosing a strategy for all participants in the system, however, from the results obtained, it can be seen that strategies are not optimal for individual participants who are forced to change their behaviour, which leads to a shift in the final result of the entire system. From the standpoint of the system as a whole, participants whose indicators are below the average are acceptors, at the expense of participants whose indicators are higher than the average values within the system.

4. Conclusion
As a result of the study, the effectiveness of the use of neural network technologies was shown in order to identify groups of system objects with similar production indicators. The allocation of clusters allows you to develop separate programs for effective interaction within the system. So, a different level of dispersion between the objects of the system indicates a different risk for a group of objects, which poses a threat to the stable operation of the system, if this is not taken into account. Developing a strategy for managing individual groups solves this problem.

An important result here is the reconstruction of the information necessary for making management decisions, which is available to all participants in the system, which allows observing the principle of openness, which is one of the main in complex organizational and technical systems. Violation of the principle of openness leads to additional benefits without increasing risk, which should not be in a sustainable system. Avoiding such a situation will keep all participants in the system as a whole.

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