Development Strategy Model of the Informational Management Logistic System of a Commercial Enterprise by Neural Network Apparatus

Valeriy Lakhno[1[0000-0001-9695-4543]], Olena Kryvoruchko[2[0000-0002-7661-9227]], Alyona Desiatko[2[0000-0002-2284-3418]], Andrii Blozva[1[0000-0002-4377-0916]], and Viktoriia Semidotska[2[0000-0002-1333-1154]]

[1] National University of Life and Environmental Sciences of Ukraine, Ukraine
[2] Kyiv National University of Trade and Economics, Ukraine
valss21@ukr.net

Abstract. Models of the development strategy of the information and management system of logistics of the trade enterprise are an integral component that will increase the efficiency of trade enterprise management. Such a solution to the problem is possible using the neural network apparatus. The experiment is performed using the analytical platform Deductor for the construction and visualization of Kohonen maps. The Kohonen network is studied by the method of successive approximations. During the iterative learning procedure, the network is organized in such a way that the elements that correspond to the centers located close to each other in the space of entrances will be located close to each other and on the topological map. Accordingly, the algorithm of self-learning maps shows how clustering of multidimensional vectors. The constructed Kochhonen maps, which show the ratio of assets and liabilities, income and expenses of the enterprise, provide an opportunity to analyze and determine the structural indicators of the enterprise and manage them. The use of the proposed models and methods made it possible to identify the main factors and sources of improving the information management system efficiency through the use of logistics approaches and system developments.

Keywords: Kohonen Networks, Kohonen Maps, Neural Networks, Logistic Strategy, Information System, Management System.

1 Introduction

Management of the trade enterprise logistics information systems as part of a single information space of the organization and the use of various content and form components of the information resource management system is associated with the development of new approaches and means of combining the interaction of material, financial and information flows.

Coordinated management of logistics information systems and the use of various in content and form components of the information resource of trade enterprise management systems is an important problem that requires the use of scientific approaches and means to solve it.

Designing an information management system for logistics of a trading enterprise is a complex and multifaceted process that uses all the achievements of modern information technologies, each of which makes it possible to manage the organization and interaction of structural units of the enterprise successfully.

One of the important ways to increase the efficiency of trading companies and networks is creating an effective information management system, which is a set of tools, techniques, artists, providing the information necessary and sufficient implementation of all operational management processes, and the use of modern information technology.

Thus, the design of a model strategy for the development of information and management systems of trade enterprise logistics is quite relevant and the introduction of such an information system will increase the efficiency of the management of trade enterprises.

To solve this problem, it is proposed to use the means of the neural network apparatus. The increase in information about all production, technological processes and equipment, raw materials and their quality, range of updated products, staff skills, market relations lead to a significant complication of management tasks and especially in making the right effective decision, implementation of business ideas, creating the strategy of development in the process of enterprise management and the industry as a whole.

An important role is played by information and management systems, which combine the positive qualities of technical electronic means of collecting information, it is processing, and the person as a direct participant in the formation of management actions, effective decision-making on enterprise management.

The article aims to use the method of construction of Kohonen maps to find patterns in the data, which allows for exploratory analysis of data, which differs from classical statistical procedures. Based on the forecast, obtain a prediction of the values of the time series for the number of samples, which corresponds to a given forecasting horizon (this is a financial structure that will correspond to the required level of commercial enterprises). Conduct an experiment using the Deductor analytical platform to build and visualize Kohonen maps.

2 Literature Review

Effective application of various approaches and methods of modeling to the strategy of development of information and management system of the trade enterprise logistics acquires a decisive advantage in building business models of trade enterprises. The use of neural network apparatus is proposed, in particular the use of Kohonen networks and Kohonen maps.

Kohonen mapping methods described in the works of authors Chang, Wui Lee, Pang, Lie Meng, Tay Kai Meng [1–3], in their study the authors O. Kryvoruchko, A. Desiatko issues identified information and control of logistics trading enterprises [4–8], and in the writings scholars V. Lakhno, Y. Matus, V. Malyukov, S. Tsiutsiura, Y. Ryndych, A. Blozva, A. Desiatko, O. Kryvoruchko, and others [8–11] published on the need for cognitive components of Smart City, in particular, such as enterprise trading.

But today the issue of using Cohonen networks and Cohonen maps in modeling the strategy of development of information and management system of logistics of a trading enterprise is not sufficiently revealed and studied.

3 Models and Methods

One of the methods used to build commercial enterprise information and management logistic system is the use of artificial neural networks. Artificial neural networks are a collection of neural elements and the connections between them. The main element of a neural network is a formal neuron.

The principle of operation of such a neuron is as follows: the input signals (x_n), which have the appropriate weights (w_n), are grouped and pass through the transfer function, generate the result and at the final stage, the output is obtained.

Various learning algorithms and their modifications are used for network training. One of the methods used to build commercial enterprise information and management logistic system is the use of Kohonen neural networks and Kohonen maps [1].

Kohonen networks (layers) [1–3] belong to self-organized neural networks. A self-organized network allows you to identify clusters (groups) of input vectors which have some common properties.

Clustering is the division of a large number of objects under study into groups of identical (similar in properties) objects, called clusters [2]. Synonyms of the term “cluster” are the terms class, taxon, thickening. The task of clustering is fundamentally different from the task of classification.

Solving problems of classification is to assign each object to one of the predefined classes. The division of objects into clusters is carried out while forming clusters. Kohonen networks are used to cluster objects that are described by quantitative characteristics

Kohonen network has only two layers: input and output, called self-organizing map. The elements of the map are located in some space, usually two-dimensional.

Kohonen network operation algorithm:

1. Network initialization. The weights of the network are given small random values. The initial neighborhood area is shown.
2. Presenting the network with a new input signal.
3. Calculation of the distance to all neurons in the network is the distances d_j from the input signal to each neuron j are determined by the formula:

$$d_j = \sum_{i=1}^{N} (x_i(t) * w_{ij}(t))^2 \quad (1)$$

where x_i is the i^{th} element of the input signal at time t, $w_{ij}(t)$ is the importance of the connection from the i^{th} element of the input signal to the neuron j at time t.

4. Selection of the neuron with the shortest distance is the winning neuron j^* is selected, for which the distance d_j is the smallest.
5. Adjusting the weights of the neuron j^* and its neighbors is the scales are adjusted for the neuron j^* and all neurons from its vicinity NE. New weight values:

$$(t + 1) = w_{ij}(t) + r(t)(x_i(t) - w_{ij}(t)). \tag{2}$$

6. Return to step 2.

The algorithm uses the coefficient of learning speed, which is gradually reduced for a more subtle correction at a new level As a result, the position of the center is set in a certain place, which qualitatively clusters the examples for which the neuron is the winner.

In the learning algorithm, the correction is applied not only to the winning neuron but also to all neurons in its current environment. As a result of this change of environment, the initial rather large sections of the network migrate towards the educational examples [2, 3].

The network forms a rough structure of topological order, in which similar examples activate groups of neurons that are closed on the topological map. With each new era, the learning speed and the size of the environment decrease, thus within the areas of the map are more subtle differences, which ultimately leads to a more precise adjustment of each neuron. Often training is deliberately divided into two phases: shorter, high-speed training, and large neighborhoods, and longer training with low learning speed and zero or near-zero neighborhoods. Once the network is trained to recognize the structure of data (goods), it can be used as a visualization tool in data analysis.

The algorithm of functioning of self-learning maps (Self Organizing Maps, SOM) is one of the options for clustering multidimensional vectors. An example of such algorithms is the *k*-means algorithm [2, 5]. An important difference of the SOM algorithm is that in it all neurons (nodes, centers of classes) are arranged in some structure (usually a two-dimensional grid). In this case during training not only the winning neuron is modified, but also its neighbors (to a lesser extent). Due to this, SOM can be considered as one of the methods of designing multidimensional space in space with a lower dimension. When using this algorithm, vectors similar in the source space are detected side by side on the resulting map. SOM involves the use of an ordered structure of neurons. Usually, one and two-dimensional grids are used. Each neuron is an n-dimensional column vector [1–3]

$$w = [w_1, w_2, \dots w_n]^T \tag{3}$$

where n is determined by the dimension of the output space (dimension of the input vectors).

The use of one- and two-dimensional grids is since there are problems with the display of larger dimension spatial structures (problems with reducing the dimension to two-dimensional appear again).

Usually, neurons are located in nodes of a two-dimensional grid with rectangular or hexagonal cells. In this case, as already mentioned, neurons also interact with each other. The magnitude of this interaction is determined by the distance between the neurons on the map.

This is easy to see that a hexagonal grid distance between neurons longer coincides with the Euclidean distance than for a quadrangular grid. The number of neurons in the grid determines the degree of detail of the result of the algorithm, and as a result, the accuracy of the generalizing ability of the map depends on it.

Kohonen maps (self-organizing map or SOM) [1–3] are designed for the visual representation of multidimensional properties of objects on a plane with two axes. Kohonen maps conduct mapping input data of high dimensionality on the elements of a regular array of small dimensions (usually two-dimensional). The difference between the cards and Kohonen networks is that the map neurons, which are the centers of clusters are arranged in a certain structure (usually a two-dimensional grid).

As a result, similar in some metric input vector network Kohonen belong to one neuron (cluster center), and Kohonen map can relate to different closely spaced on a grid of neurons. Usually, neurons are located in the nodes of a two-dimensional grid of rectangular or hexagonal cells. Neighbor neurons are determined by the distance between the neurons on the map.

Each cell corresponds to a neuron of the Kohonen network. The number of cells of the map depends on the required detail of the image and is selected experimentally. For each cell, one of the statistical characteristics of the selected component of the input vectors trapped in the cell is calculated [6, 9]. Kohonen map has the shape of a rectangle in the corners of which groups of the enterprise of divisions are placed, which are significantly different from another, and objects with similar characteristics are grouped in the center of the map.

Management decisions at different hierarchical levels require increasing their objectivity, which is achieved by using economic and mathematical methods in their calculation methods including multivariate statistical cluster and factor analysis, and the relatively novel approach based on Kohonen maps.

The process of creating a self-organizing map involves establishing a connection between the input and output layers of neurons and thus displays larger dimension data on a smaller dimension map, consisting of "neural lattices" [5]. The construction of the map takes place as a procedure of establishing a correspondence between input and output, in the so-called competition of neural networks. It should be noted that this method has significant advantages over cluster analysis, namely: it takes into account all the indicators selected for analysis. Thus, the maps can determine the general characteristics of each cluster's similarities and risks inherent in them. This method can be used to determine the main risks of the company trade. The first group of units, which always occupies one of the corners of the map, brings together the worst representatives, indicators of which indicate the negative activity of the logistics system, which informs about the mandatory changes in the activities of units. The angular position is always occupied by the least profitable services of the enterprise, that went to cease their activities and require change and renewal plan.

Problem areas occupy the southeast corner of the map. Each small cluster of this angle has certain features, but they all differ significantly from others by a large level of damage. Clusters located closer to the center have slightly better performance, but also combine the most problematic units of the system. In addition to the group of problem units, the Kohonen map also identifies other problem units that have unbalanced values of structural indicators. Among each of these groups, there are more or less stable clusters that are combined with the same risk profile. In the presence of structural distortions (dependencies, constraints), even a satisfactory level of individual characteristics of the logistics system can not indicate sufficient security of the trading company [4]. After analyzing and determining structural indicators that show the ratio of assets and liabilities, income and expenses of the enterprise depending on the service provided and the construction of the Kohonen map, a simple, clear, and logical visualization of the distribution of service units is provided. The service units in different segments of the map with similar characteristics differ not only in the general level of the logistics system chosen by the researcher but also in the structural features that affect its achievement.

4 Computational Experiment

Assessment of the financial condition of the trade enterprise is carried out at a qualitatively new level, taking into account its structural specifics, receipts, and analysis of funds from sales, storage, and transportation, belonging to the relevant specialized groups and the relationship between the objects of each group. The platform for building and visualizing Kohonen maps is Deductor, an analytical platform that allows you to create an effective business decision support system in a short time.

With powerful import mechanism, Deductor possible to create a unified analytical add-on to all existing company systems: “Information system protection;” “Defining the strategy and technology of resource allocation;” “Optimization of hard wear and soft wear systems;” “Transportation of goods;” “Sales of goods;” “Material flows of logistics;” “Information logistics;” etc. [4, 8]. The uniqueness of this solution is that Deductor, if necessary, automatically combines data from different sources.

Completed in Deductor based technology allows a single architecture to pass all stages of construction analysis system—from creating data warehouses to automatic selection of models and visualization of the results. Deductor provides the tools needed to solve a variety of analytical tasks. Corporate reporting, forecasting, segmentation, search for patterns—these and other tasks that use such analysis techniques as OLAP, Knowledge Discovery in Databases, and Data Mining [7]. Consider in practice the use of data from research and production private enterprise “A.V. New technologies,” taking into account the period (2018–2019). Using the data of Table 1 in Deductor Studio Academic the initial data are processed, the table is constructed, statistics have resulted and the diagram is created, results are shown in Fig. 1–3.

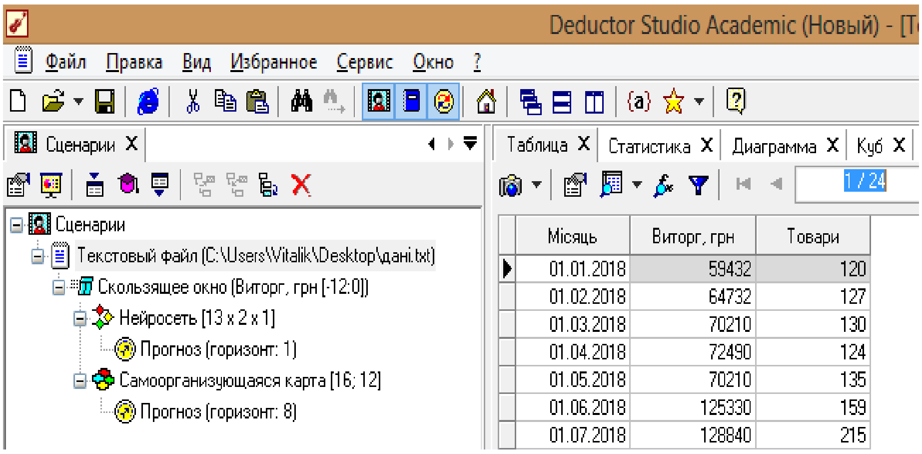

Fig. 1. Construction of the table according to the data of research and production private enterprise “A.V. New technologies.”

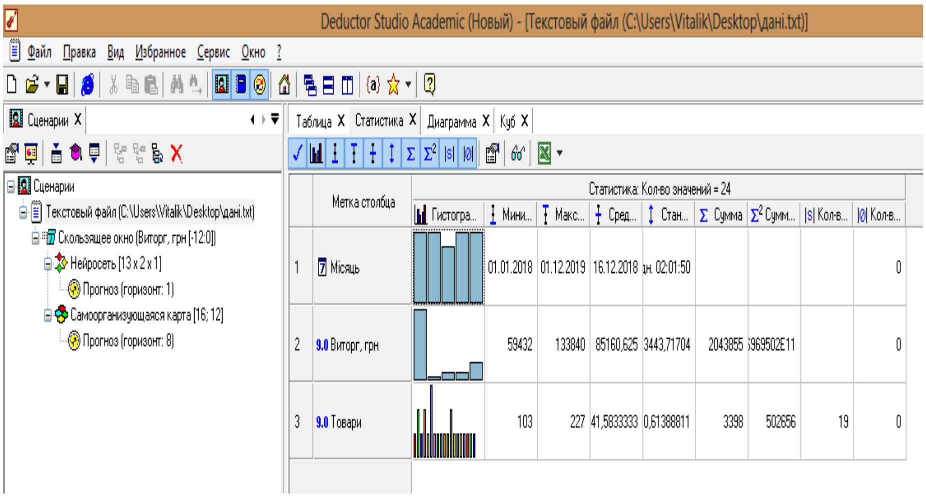

Fig. 2. Construction of statistics according to the data **o**f research and production private enterprise “A.V. New technologies.”

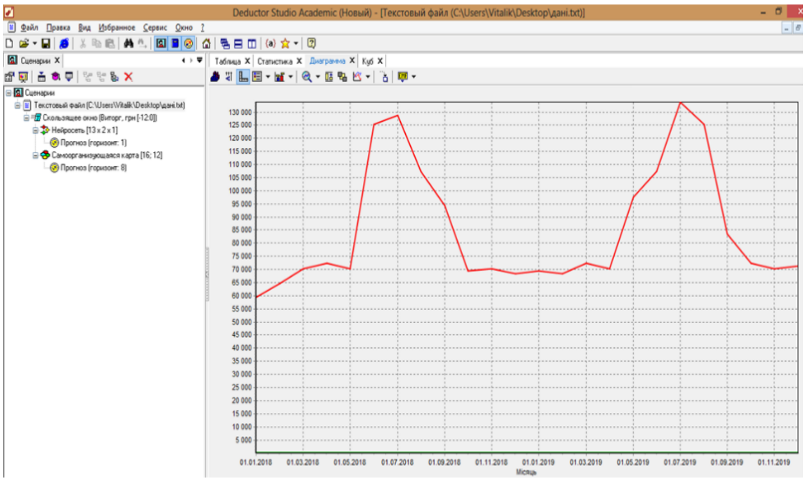

Fig. 3. The construction of the diagram is based on data from Table 1.

After processing the initial data in Deducto Studio Academic the tool “Sliding Window” is used in Fig. 4. The Sliding Window tool converts a sequence of row values into a table where adjacent records are represented as adjacent data fields (a window because only some continuous section of data is allocated, a sliding one because that window “moves” throughout the set). The need for quantitative data (tables) often occurs when building models, analyzing, and forecasting time series when applying for entry models mentioned several adjacent samples from the original data set [9]. Values in one of the record fields will refer to the current count, and in others—offset from the current count “in the future” or “in the past.” Thus, the conversion of the variable window has two parameters: immersion depth—the number of “past” samples that fall into the window; forecasting horizon—the number of “future” samples.

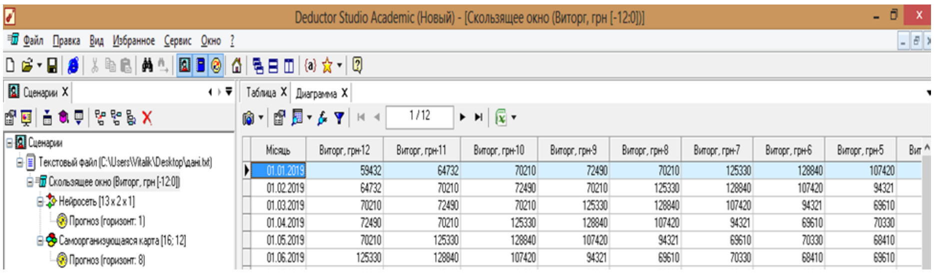

Fig. 4. Using the Sliding Window.

Based on the created “Sliding Window” Data Mining tools are used: “Neural Network” (Fig. 5) and “Self-organizing Kohonen maps” (Fig. 6) based on which the forecast of the future periods is made Fig. 7.

Neural networks are self-learning models that mimic the activity of the human brain. They are able not only to perform a once programmed sequence of actions on certain data but also to analyze the coming data [11].

The main advantage of neural networks is the ability to build an effective nonlinear dependence, a more accurate description of data sets compared to linear methods of statistics. This data processor allows you to specify the structure of the neural network, determine its parameters, and teach using one of the algorithms available in the system.

The result will be a neural network emulator, which can be used to solve problems of forecasting, classification, finding hidden patterns, data compression, and many other applications [7, 9].

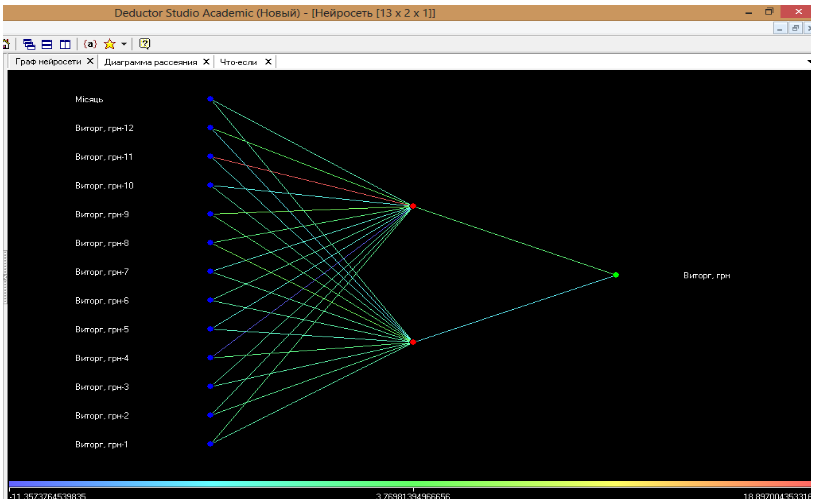

Fig. 5. Neural network graph of trading enterprise with revenue reflection according to research and production private enterprise "A.V. New technologies."

Kohonen's self-organizing maps are a powerful self-learning clustering mechanism that allows you to display results in the form of compact and easy-to-interpret two-dimensional maps. This handler is used to find patterns in large data sets. This allows for intelligence analysis of data, which differs from classical statistical procedures, during which a set of hypotheses is tested. [8, 10]. The main advantages of the algorithm: resistance to noisy data; fast and unmanaged learning; ability to visualize multidimensional input data.

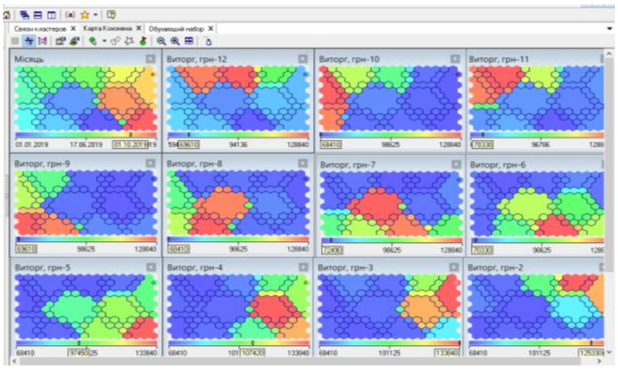

Fig. 6. Self-organizing f Kohonen maps.

Forecasting allows obtaining prediction values of time series on the number of samples that match the prediction horizon. This algorithm works as follows. Suppose that as a result of the transformation by the method of “sliding window” a sequence of time samples was obtained:

$$X\,(-n), \ldots, X\,(-2), X\; -\; (-\,1), X0, X\,(+1) \tag{4}$$

where $X\; +\; 1$ predicted value obtained by the previous processing step (for example, linear regression) based on n previous values.

Then to build a forecast for the value $X\,(+2)$, you need to move the whole sequence, one count, to the left, so that the previously made prediction $X\,(+1)$ is also included in the number of initial values. Then the algorithm for calculating the predicted value will be started again, and $X\,(+2)$ will be calculated taking into account $X\,(+1)$ and so on according to the forecast given by the horizon [9, 12, 13].

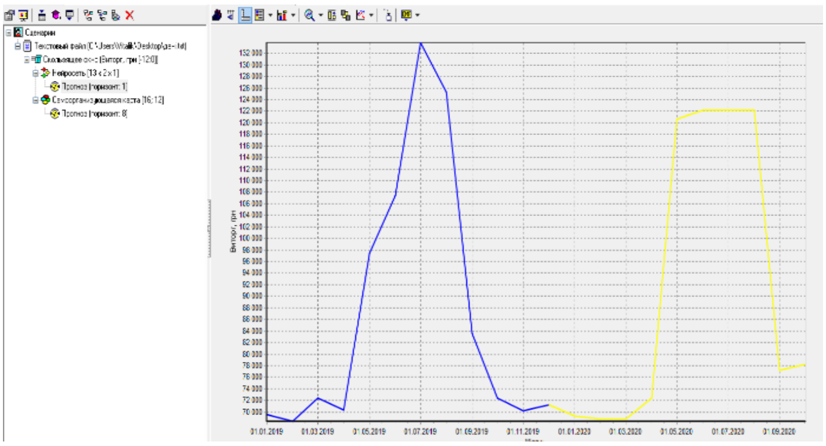

Fig. 7. Self-organizing f Kohonen maps.

5 The Result of the Experiment

Prediction built on the results of self-organizing Kohonen maps showed different results, which is logical.

Deducto Studio Academic allows you to perform various operations using Data Mining and analyzing the history of the periods of each of them to draw conclusions and use the desired result in the further activities of the trade enterprise.

6 Conclusions

We believe that the proposed apparatus of neural networks and Kohonen maps, which in contrast to the existing mathematical models reflects the results of the study in the form of visual two-dimensional maps, which allows increasing the efficiency of visualization and analysis of results and forecasting, allows not only to determine the most profitable logistics strategy but also to assess the financial condition of each object of study.

Accordingly, using the above models and methods, the main factors and sources of improving the management information system efficiency through the use of logistics approaches and system developments are identified.

The model of the strategy of development of the information-managing system of logistics of the enterprise of trade using the device of neural networks is presented. It suggests that this approach encourages companies to apply strategies based on cognitive scientific methods and methodologies.

In the future authors plan to research concepts of modeling of informational management system strategy to implement this in Smart City models.

References

1. Chang, W. L., Meng, P. L., Meng, T. K.: Application of self-organizing map to failure modes and effects analysis methodology. Neurocomput. **249**: 314–320 (2017). https://doi.org/10.1016/j.neucom.2016.04.073
2. Shah-Hosseini, H.: Binary tree time adaptive self-organizing map. Neurocomput. **74**(11): 1823–1839 (2011). https://doi.org/10.1016/j.neucom.2010.07.037
3. Gorban, A. N., Zinovyev, A.: Principal manifolds and graphs in practice: from molecular biology to dynamical systems. Int. J. Neural Syst. **3**(20): 219–232 (2010). https://doi.org/10.1142/s0129065710002383
4. Desiatko, A., Kryvoruchko, O.: Integrated flows in logistics. Build-Master-Class Work. Progr. Proc. Int. Sci.-Pract. Conf. Young Sci. (2017). [Publication in Ukrainian]
5. Doran, G. T.: There's a S.M.A.R.T. Way to Write Management's Goals and Objectives. Manag. Rev. **11**(70): 35–36 (1981)
6. Torres, L., Pina, V., Royo, S.: E-government and the transformation of public administrations in EU countries: beyond NPM or just a second wave of reforms? Online Inf. Rev.: **5**(29): 531–553 (2005). https://doi.org/10.1108/14684520510628918

7. Lakhno, V., Malyukov, V., Kryvoruchko, O., Desiatko, A.: Model of evaluating smart city projects by group of investors using a multifactorial approach. Appl. Technol. First Int. Conf. **1193**: 13–27 (2020). https://doi.org/10.1007/978-3-030-42517-3_2
8. Lakhno, V., Matus, Y., Malyukov, V., Desiatko, A.: Smart city cybersecurity projects financing model in case of description of investors' resources with fuzzy. IEEE Int. Conf. Adv. Trends Inf. Theory: 249–252 (2019). https://doi.org/10.1109/ATIT49449.2019.9030499
9. Lakhno, V., Tsiutsiura, S., Ryndych, Y., Blozva, A., Desiatko, A., Usov, Y., Kaznadiy, S.: Optimization of information and communication transport systems protection tasks. Int. J. Civ. Eng. Technol. **1**(10): 1–9 (2019)
10. Hollnagel, E., Woods, D. D.: Joint Cognitive Systems: Foundations of Cognitive Systems Engineering (2005). https://doi.org/10.1201/9781420038194
11. Lakhno, V., Malyukov, V., Kasatkin, D., Blozva, A., Litovchenko, T.: Model for supporting decisions of a group of a smart city project investors, taking into consideration multifactoriality. Cybersecur. Edu. Sci. Tech. **6**(2): 57–70 (2019). https://doi.org/10.28925/2663-4023.2019.6.5770
12. Lakhno, V., Malyukov, V., Plyska, L. D.: Model of investment strategies of transport situational centers in cyber security systems. Cybersecur. Edu. Sci. Tech. **2**(2): 68–79 (2018). https://doi.org/10.15588/1607-3274-2018-2-9
13. Rzaieva, S., Rzaiev, D., Kraskevich, V., Roskladka, A., Gamaliy, V.: Automated logistic flow system for trading enterprise. Cybersecur. Edu. Sci. Tech. **7**(3): 72–84 (2020). https://doi.org/10.28925/2663-4023.2020.7.7284