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THE USE OF NEURAL NETWORK MODELING TO PREDICT THE VOLUME OF ENTERPRISE SALES

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The article is devoted to research the problem of application of neural network modeling to improve the quality of forecasting sales of the enterprise. The use of the artificial neural network model – one of the means of artificial intelligence – to predict the sales of the enterprise due, on the one hand, unsatisfactory results of traditional quantitative forecasting methods, and, on the other hand, the implementation of the Concept of Artificial Intelligence in Ukraine. In order to analyze the results of the use of neural network modeling to forecast sales of the enterprise, it is developed the method of analysis based on comparative analysis of the quality of forecast models of four classes (groups): I – regression, II – autoregressive, III – nonlinear trend (considered in different periods) and IV – neural network. Neural network models were considered in three types: 1) neural network input-output (net), 2) neural network based on the NAR model (nonlinear autoregression), 3) neural networks of NARX type – nonlinear autoregression with external (exogenous) input. Approbation of the methodology was carried out on the data of the company "Sportmaster" – a company that trades throughout Ukraine. The criterion for assessing the quality of the model is the average absolute percentage error (MAPE). Approbation of the method of analysis of the results of the use of neural network modeling to forecast sales of the enterprise revealed that the best models for forecasting and analysis were neural networks NAR and NARX (group IV), and slightly worse, by evaluation, was autoregressive model (group II), built on a long period 276 values. Thus, it was found that the use of neural network models allow to obtain a more accurate forecast of sales for the trading company, which confirms the feasibility of their use. It is proposed to improve the model of sales policy of the enterprise through the use of neural network modeling to forecast sales, which creates conditions for improving the efficiency and competitiveness of the enterprise. The results of the study can be used as a basis for improving the existing information systems of enterprise management.

ЗАСТОСУВАННЯ НЕЙРОМЕРЕЖЕВОГО МОДЕЛЮВАННЯ ДЛЯ ПРОГНОЗУВАННЯ ОБСЯГІВ РЕАЛІЗАЦІЇ ПІДПРИЄМСТВА

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Ключові слова:
підприємство, обсяги реалізації, нейромережеве моделювання, прогнозування

Стаття присвячена дослідженню проблеми застосування нейромережевого моделювання для підвищення якості прогнозування обсягів реалізації продукції підприємства. Застосування моделі штучної нейронної мережі – одного із засобів штучного інтелекту – для прогнозування обсягів реалізації підприємства зумовлені, з одного боку, незадовільними результатами застосування традиційних кількісних методів прогнозування, а, з іншого боку, завданнями реалізації в сфері економіки Концепції розвитку штучного інтелекту в Україні. З метою аналізу результатів застосування нейромережевого моделювання для прогнозування обсягів реалізації продукції підприємства запропоновано методику аналізу, яка базується на порівняльному аналізі якості прогнозних моделей чотирьох класів (груп): I – регресійні, II – авторегресійні, III – нелінійні трендові (які розглядалися на різних періодах ретроспекції) та IV – нейромережеві. Нейромережеві моделі розглядалися трьох видів:

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1) нейромережа введення–виведення (net), 2) нейромережа на основі моделі NAR (нелінійна авторегресія), 3) нейромережа виду NARX – нелінійна авторегресія з зовнішнім(екзогенним) входом. Апробація методики проведена на даних підприємства ТОВ «Sportmaster» – підприємства, яке займається торгівлею по всій Україні. Критерієм оцінки якості моделі обрано середню абсолютну відсоткову похибку (MAPE). Апробація методики аналізу результатів застосування нейромережевого моделювання для прогнозування обсягів реалізації продукції підприємства виявила, що кращими моделями для прогнозування та аналізу виявилися нейромережі NAR та NARX (група IV), та з дещо гіршою оцінкою авторегресійна модель (група II), побудована за довгим періодом ретроспекції (276 значень). Таким чином, виявлено, що використання нейромережевих моделей дає змогу отримати більш точний прогноз обсягів реалізації для торговельного підприємства, що підтверджує доцільність їх використання. Запропоновано удосконалення моделі формування збутової політики підприємства за рахунок використання нейромережевого моделювання для прогнозування обсягів продажів, яка створює умови для підвищення ефективності та конкурентоспроможності підприємства. Результати дослідження можуть бути покладеними в основу удосконалення існуючих на сьогодні інформаційних систем управління підприємствами.

Statement of the problem

Forecasting is an integral part of every modern business. In market conditions, the results of forecasting are necessary to determine the direction of further development of the enterprise, understanding the state of the environment in which it operates, planning effective use of resources, prevention of possible negative factors and more. One of the central indicators in planning at the enterprise is the projected volume of sales of products (works, services). This indicator serves as a basis for planning the leading business processes in the enterprise and affects the efficiency and competitiveness of the enterprise.

Particular important is the problem of ensuring the highest possible quality of forecasts. The solution to this problem is to justify and choose a relevant forecasting method.

Today there is a well-developed arsenal of qualitative and quantitative forecasting methods. Quantitative methods are based, as a rule, on traditional approaches and models (statistical, extrapolation, network and others). However, the existence of such a wide variety of methods suggests that the results of their application are not always acceptable, and in the field of economics lead to unacceptable losses.

According to the Concept of Development of Artificial Intelligence in Ukraine adopted in [1], one of the priority areas of its implementation is the introduction of artificial intelligence technologies in the economy. In particular, one of the tasks of the Concept is to motivate business entities to introduce artificial intelligence technologies to increase their own efficiency. In the light of these tasks, the urgent problem is the use of one of the means of artificial intelligence – the model of artificial neural network to predict the volume of sales of the enterprise.

Analysis of latest research and publications

In [2] the issue of estimating the logistical risks of enterprises on the basis of sales forecasting is investigated. This paper proposes the concept of logistical risk of forecasting demand and developed a method for estimating the logistical risk of forecasting demand by two estimates: the accuracy of the trend model for forecasting and the accuracy of the forecast taking into account seasonality.

The work [3] is devoted to the quantitative assessment of the activities of agricultural enterprises in the Volyn region in terms of sales of products (goods, works, services).

In papers [4–6] the modern directions of improvement of the system of financial planning and forecasting of the enterprises of Ukraine were investigated. Along with the analysis of the criteria for assessing the financial condition and results of the enterprise, the methods of forecasting and planning the turnover of the enterprise are considered. Article [6], in particular, is devoted to a comparative analysis of existing methods of forecasting economic indicators for a commercial enterprise. However, real results of the assessment of the quality of forecasts by the above methods were not provided.

In [7] (Sakun A. Zh., Pantiuk I.P.) theoretical and methodological aspects of the system approach are considered, which provides consideration of the enterprise as a complex of subsystems (production, sales, warehousing, transport and other activities). The results of this work are important for determining the place of the indicator of sales of the enterprise to ensure the effective functioning of the enterprise.

Along with the already widespread methods [8], new methods are actively involved in the arsenal of forecasting.

Thus, in [9] the author explored the possibilities of creating and applying artificial intelligence systems, methods of neural network theories and fuzzy logic in economics, and in [10] – studied the use of neural networks in the analysis of macroeconomic indicators.

Effective methods of working with Big Data and their application for forecasting are investigated in [11; 12]. However, insufficient attention has been paid to the problem of using neural networks to forecast the company's sales.

Goals formulation

The purpose of the article is to analyze the results of the use of neural network modeling to improve the quality of forecasting sales of the enterprise.

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Presentation of the main research material

The continuity of the production process, the turnover of working capital, the results of financial and economic activities, the profitability of the enterprise depend on how the sales system is organized.

According to the current legislation, the company sells its products and other tangible assets on the basis of direct agreements (contracts) established by the state, through commodity exchanges, through the network of its trading companies. The growth rate of sales, improving its quality directly affect the cost, profit and profitability of the industry.

Thus, based on forecasting sales, the company has the opportunity to regulate and balance its activities. The number of products produced and sold (productivity, organization of services) are the main indicators that represent the activities of the organization, and the forecast of these indicators is important for assessing their activities both at the planning stage and at the implementation stage.

The rapid development of the use of information technology in business management has led to the need to find new forecasting methods, the use of which gives a competitive advantage in the industry.

The use of neural networks allows you to take into account the factors on the basis of which you can build short-term forecasts. Using a neural network architecture (perceptron with one hidden layer) and a database (retail turnover and other data from the external and internal environment), it is possible to obtain an effective forecasting system [6].

To substantiate the use of neural networks in forecasting the volume of sales of the enterprise, we will conduct a comparative analysis of the results of the application of different forecasting methods to the relevant time series (Fig. 1).

Lets conduct research on the application of the proposed methodology on the information base of the company «Sportmaster» – a company that trades throughout Ukraine in sporting goods through the online platform [13] and off-line outlets.

The dynamics of sales volumes of Sportmaster LLC for the period from January 1, 2021 to October 25, 2021 is presented in Fig. 2

To use the technique presented in Fig. 1, we construct four groups of predictive models (I–IV).

I group of models – regression models.

We select the following variables as input data for model construction:

Y_t – sales volume (revenue per day) on day *t*,

$X^1_{(t-1)}$ – sales volume per day ($t-1$), (value of revenue for the day last year),

$X^2_{(t-1)}$ – number of visitors per day $t-1$ (value of the number of visitors per day),

$X^3_{(t-1)}$ – number of visitors per day ($t-1$) in the previous year (value of the number of visitors per day in the previous year),

$X^4_{(t-1)}$ – conversion (the ratio of revenue to the number of visitors per day ($t-1$)).

Construct a regression model in the form (1).

$$Y_t = \beta_0 + \beta_1 X^1_{(t-1)} + \beta_2 X^2_{(t-1)} + \beta_3 X^3_{(t-1)} + \beta_4 X^4_{(t-1)}, \quad (1)$$

where $\beta_0, \ldots, \beta_4$ – regression coefficients.

After excluding insignificant variables, the regression model has the form (2):

$$Y_t = 106274,6727 + 0,56837602 * X^1_{t-1} + \\ + 20,3680408 * X^2_{t-1}, \quad (2)$$

where X^1_{t-1} – the value of the indicator «Sales volume for the past period»; X^2_{t-1} – value of the indicator «Number of visitors for the previous period».

According to Fisher's criterion, the model turned out to be significant F_p=33,26545978 and $F_к$=1,217523008.

To compare the results of forecasting using regression models, we build a regression model based on the last 30 values. When building a regression model for the last 30 values, the variables X^1_{t-1} «Sales volume (last year)», X^2_{t-1} – «Visitors», $X_{4(t-1)}$ – «Conversion»were not significant. According to Fisher's criterion, this model was also significant (F_p = 55,49025734 and $F_к$ = 1,868709158) and has the form (3):

$$Y_t = -59860,11726 + 382,4861479 * X^3_{t-1}, \quad (3)$$

where X^3_{t-1} – the value of the data «Visitors (last year) for the past period».

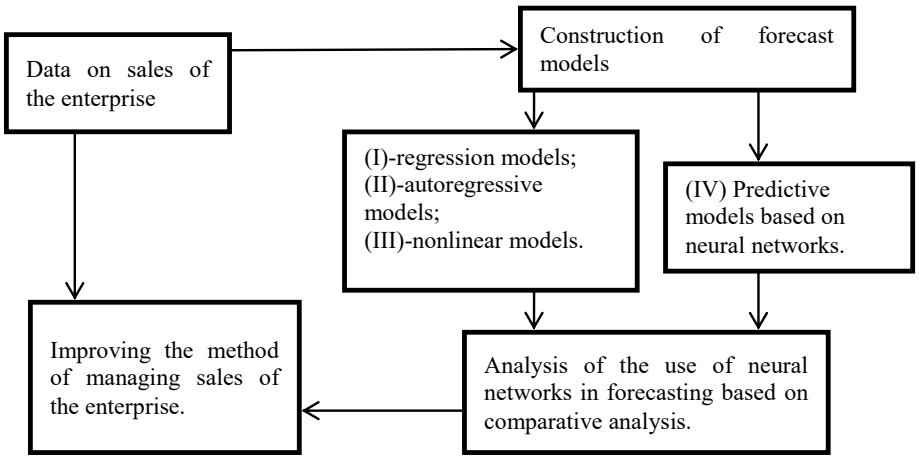

Fig. 1 – Schematic model of research of application of neural networks in forecasting of volumes of realization of the enterprise

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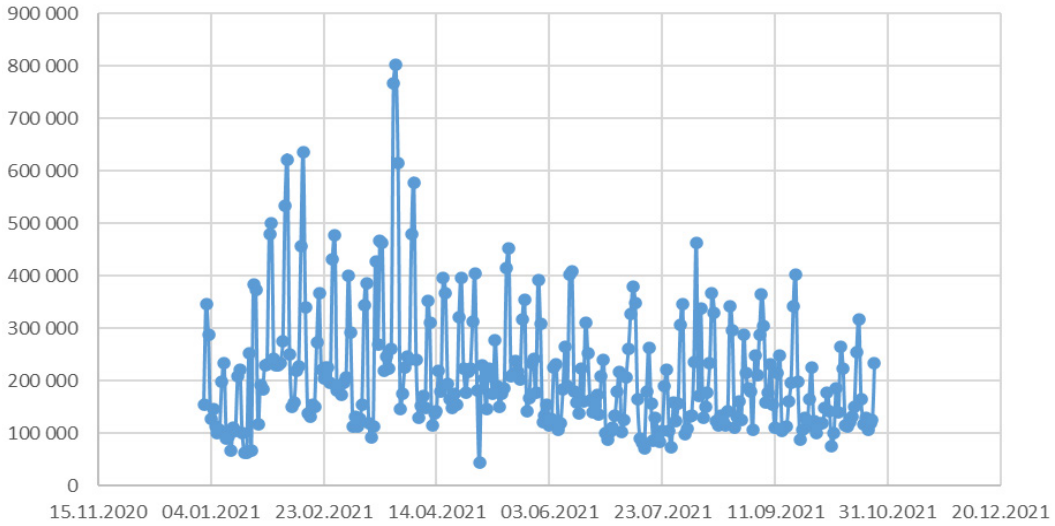

Fig. 2 – Dynamics of sales volumes (thousand UAH) of Sportmaster LLC in 2021

To check the quality of the models, we use the average absolute percentage error (MAPE):

$$MAPE = \frac{100}{\tau} \sum_{t=T+1}^{T+\tau} \left| \frac{x_t - \hat{x}_t}{x_t} \right|. \quad (4)$$

According to the MAPE values, the second regression model (3) was better than the first (2) (34.4% <39.7%).

II group of models – autoregressive models.

Let's build a linear autoregressive model in the form of (5) and check its quality to predict the volume of sales:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \beta_3 Y_{t-3} + \\ + \beta_4 Y_{t-4} + \beta_5 Y_{t-5} + \beta_6 Y_{t-6} + \beta_7 Y_{t-7}, \quad (5)$$

where Y_t – sales volume (value of revenue per day) per day t.

Note that the use of the previous 7 values in the construction of linear autoregression is justified by the presence in the dynamics of sales of the enterprise cyclical period $\tau = 7$.

As a result of the obtained autoregressive model in the form of (6):

$$Y = 59913,93726 + 0,424782064 * Y_{t-1} - \\ -0,128803009 * Y_{t-2} + -0,108383078 * Y_{t-5} + \\ + 0,150485653 * Y_{t-6} + 0,378672112 * Y_{t-7}. \quad (6)$$

When constructing the model, the variables Y_{t-3} and Y_{t-4} turned out to be insignificant. After excluding them from the model, the model turned out to be significant with estimates F_p = 45.39891697 and $F_к$ = 1.220899795 according to Fisher's criterion.

Let's build the second autoregressive model on 30 values and check the quality of the constructed forecast on the MAPE value.

The result is an autoregressive model in the form of (7):

$$Y_t = 125852,526 + 0,736685 * Y_{t-1} - \\ -0,462959 * Y_{t-2} - 0,401845 * Y_{t-5} + \\ + 0,350310 * Y_{t-6}. \quad (7)$$

When constructing autoregression based on 30 values, three variables were not significant: Y_{t-3}, Y_{t-4} and Y_{t-7}. In general, the model turned out to be significant according to Fisher's criterion F_p = 6,375638401 and $F_к$ = 1,91918774.

The linear autoregression model, which was based on 276 observations, provides a better prediction. This can be seen in the value of MAPE, for the first model 22.8% and for the second 26.2%.

Group III of forecast models – nonlinear trend models.

Let's check the possibility of using nonlinear trend models to forecast sales. In the table 1 presents the results of modeling – built three trend models (in which $x = Y_{t-1}$) with estimates of their quality.

Group IV – neural network models

To predict the volume of sales of the enterprise by means of neural network modeling, we use Matlab software for the design and training of neural networks Neural Time Series (ntstool) [8].

This tool allows you to solve three types of nonlinear time series. We will build these models to forecast sales volumes.

Let's build a neural network of input-output (*net*). Two networks are involved in this network: the input series $x(t)$ and the output series $y(t)$. We predict the value of $y(t)$ from the previous values of $x(t)$, but without knowing the previous values of $y(t)$:

$$y(t) = f\left(x(t-1), \ldots, x(t-d)\right). \quad (8)$$

Table 1 – The results of building nonlinear trend models for forecasting sales with estimates of their quality

Model	R^2	Model error (MAPE)
$Y_t = 10392 \times \ln(x) + 259898$	0.0088	50%
$Y_t = 216229 \times x^{-0.029}$	0.0035	41,6%
$Y_t = -2.0871 \times x^2 + 329.18 \times x + 220755$	0.0542	23,5%

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At the input of the model we use data on the following variables: sales last year (X_1, value of revenue per day last year), number of visitors (X_2, value of number of visitors per day), number of visitors last year (X_3, value of visitors per day last year), conversion (X_4, the ratio of revenue to the number of visitors per day). The total amount of data at the input will be equal to 283, 15 observations will be left to analyze the quality of the forecast model.

The source array will be the value of sales for the next period of time. In total, the number of observations will be 283, as well as the input data. Input and output data will be specified by columns.

Maltab uses three algorithms to study the neural network: Levenberg – Marquardt, Bayesian ordering, and scalable conjugate gradient. We will use the Levenberg-Marquardt algorithm because it has a number of advantages, including good work with large data sets and fast operation of the algorithm.

Let's build a neural network based on the *NAR* model (nonlinear autoregression). The calculation of the value of sales in the model is based on formula (9):

$$y(t) = f\left(y(t-1),\ldots,y(t-d)\right). \quad (9)$$

That is, in this neural network, the input of the learning network will be equal to the output. In our case, at the entrance we will give 283 values of the company's sales for 2021.

Construct a neural network of the form *NARX* – nonlinear autoregression with external (exogenous) input. This model combines the two previous models, ie has the ability to set the input parameters of the impact on sales volumes, as well as the forecast to use past values of sales:

$$y(t) = f\left(x(t-1),\ldots,x(t-d), y(t-1),\ldots,y(t-d)\right). \quad (10)$$

On the input models we will use the parameters of sales volume for the last year (X_1, the value of revenue for the last year), the number of visitors (X_2, the value of the number of visitors per day), the number of visitors last year (X_3, the value of the number of visitors per day last year), conversion (X_4, the ratio of revenue to visitors per day). At the output for network training we give the value of sales, the total number of observations 283.

Let's move on to the general simulation results. Let's analyze the quality of the developed models by comparing the values of MAPE error, which are presented in table 2.

Thus, the best models for prediction and analysis are NAR and NARX neural networks, as well as autoregression of 276 values.

That is, neural networks provide an opportunity to obtain a more accurate forecast of sales for the company, which justifies their use to improve the quality of sales activities.

The use of neural networks will allow you to more effectively plan the results of sales activities by increasing the accuracy of forecasts. The improved model of sales activity of the enterprise is presented in fig. 3.

Conclusions

The results of the use of neural network modeling to improve the quality of forecasting sales of the enterprise are analyzed in the paper. For this purpose, a method of analysis is proposed, which is based on a comparative analysis of the quality of predictive models of four classes: I – regression, II – autoregressive, III – nonlinear trend and IV – neural network. Neural network models, in turn, were considered in three types: 1) neural network input-output (net), 2) neural network based on the NAR model (nonlinear autoregression), 3) neural networks of NARX type – nonlinear autoregression with external (exogenous) input.

The research was conducted on the basis of the information base of Sportmaster LLC, an enterprise engaged in trade throughout Ukraine.

The quality of the forecast for each of the models is assessed.

In the process of researching results of predictive models, it was found that the best models for prediction and analysis were neural networks NAR and NARX, as well as autoregressive model for 276 values.

That is, the use of neural network models allow to obtain a more accurate forecast of sales for the trading company, which justifies their use to improve the quality of management (including sales) activities.

An improved model of sales policy of the enterprise with the use of sales forecasting based on the use of neural network modeling, which creates conditions to improve the accuracy of marketing forecasts, increase the efficiency and competitiveness of the enterprise.

Prospects for further research are in the expanding the information base of the study. The results of this paper can be used as a basis for improving the existing ERP-systems – integrated information systems for enterprise management.

Table 2 – Comparison of models quality

Model	The value of the MAPE	Ability to forecast for more than 1 period
Regression (n = 282)	39,7%	–
Regression (n = 30)	34,4%	–
Autoregression (n = 276)	22,8%	+
Autoregression (n = 30)	26,2%	+
Trend model (logarithmic)	50%	+
Trend model (step)	41,6%	+
Trend model (polynomial)	23,5%	+
Neural network (net)	23,3%	–
Neural network (NAR)	16,6%	+
Neural network (NARX)	17.4%	–

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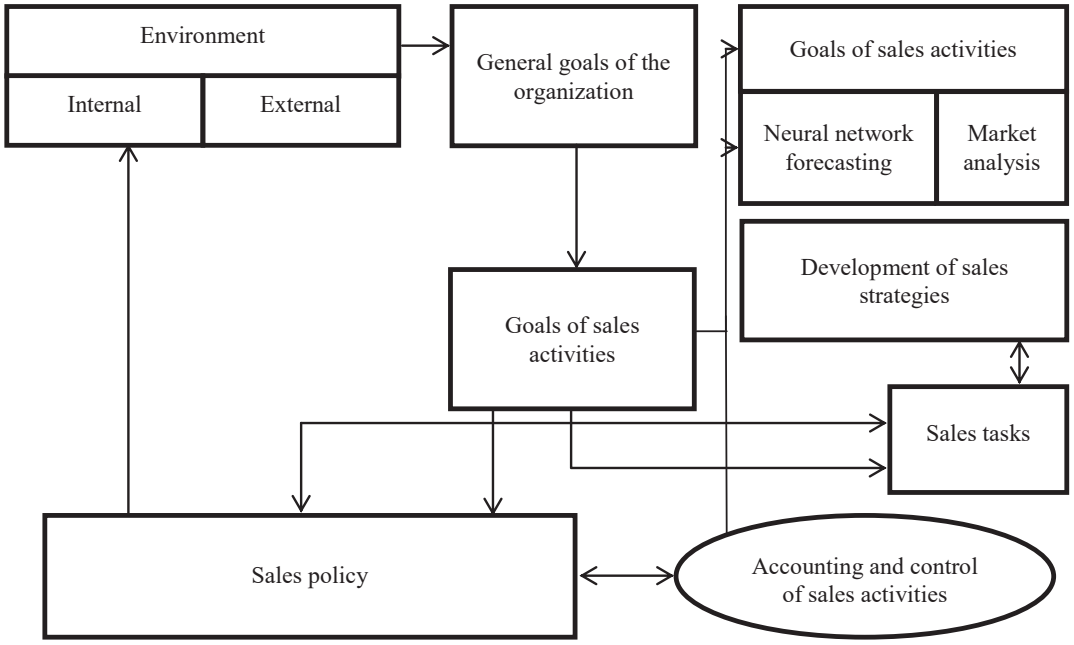

Fig. 3 – Improved model of formation of sales policy of the enterprise

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