Approaches to solving the resource supply problem of the railway company based on intellectual data analysis

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Abstract. The purchase of trade establishments is an important and complex process, on which companies spend a lot of resources in order to get the maximum benefit. There are many well-established methods for making a forecast of the required number of goods, but none of them can guarantee an accurate result, because in the matter of forecasting, there cannot be a method that produces a result with 100% accuracy. The object of our research is the process of creating a purchase forecast for trade enterprises. The subject is the analysis of the quality of the purchase forecast for retail outlets. To determine the quality of the purchase forecast of the retail outlets, it is necessary to understand how the purchasing process takes place, as well as highlight the factors that affect the forecast quality.

1. Introduction

Purchasing work is the backbone of commercial activities in trade. Commercial work essentially begins with it. To sell a product to a buyer (consumer) and make a profit, you need to have (own) the product.

Obviously, suboptimal procurement planning entails losses [1]. On the one hand, with excessive purchase of goods, freezing of funds occurs, there is a decrease in turnover, an overstocking of warehouse space and, consequently, a lack of space and under-purchase of other goods. The risk of losses from the expiration of the shelf life of the goods increases [2]. On the other hand, if there is insufficient or late purchase, the lack of goods on the shelf reduces sales and reduces customer loyalty [3, 4].

A specially trained person is engaged in forecasting purchases manually or using special software. It all depends on the size of the outlet and the criteria that must be taken into account.

Figure 1 shows the algorithm for delivering goods from the manufacturer to the end customer.

There are a lot of factors that influence purchases. These factors can be both external and internal. Table 1 provides a list of external and internal factors.

External factors are factors that cannot be influenced by a trading company, internal factors directly depend on the activities of the company.

This list includes obvious factors, some of which are used by many methods for forecasting, but the list contains factors that are aimed at the universality of the forecast. For example, a payment method.
Figure 1. Life path of goods associated with a retail outlet.

Table 1. Parameters for the input layer of the neural network.

| External factors                          | Internal factors                                                                 |
|------------------------------------------|----------------------------------------------------------------------------------|
| Customer demand. Indicator from 0 to 1   | Sales volume for previous periods. The number of items sold                       |
| Supplier reliability. Indicator from 0 to 1 | The number of unsold goods                                                        |
| Influence of competitors. Indicator from 0 to 1 | The trend of the emergence of new products in a particular category. Index from 0 to 1 |
| Seasonality of the product. Seasonal or non-seasonal item | Price for one unit of goods                                                        |
| Are there any delivery delays? Indicator from 0 to 1 | There is payment by card (0 or 1)                                                  |
|                                           | Product quality. Indicator from 0 to 1                                            |
|                                           | Is there a marketing campaign planned (0 or 1)                                    |

In Europe, buyers have no problems to carry cash with them, so the lack of card payment will not greatly reduce the income of the outlet, and in Russia people in large cities are accustomed to using a bank card, so if the outlet introduces a card payment system, it will have, in the near future, to buy more goods, because its sales will increase.

The importance of the above factors is obvious, but for practical use they must be converted into numerical values. This requires deciding which parameters are most important, how they are determined and whether they are continuous or discrete.
2. Artificial neural networks: essence, training and types

Artificial neural networks (ANN) are very popular to solve the prediction problems [5 - 7]. Figure 2 shows a graph of the growth in the number of publications in the Scopus citation system for the request "Neural networks" (neural networks).

![Graph of growing interest in the topic "Neural networks" (neural networks).](image)

Interest in the topic only grows every year. To solve the regression problem, we need to choose the correct architecture of the neural network [8, 9].

The choice of the structure of the neural network is carried out in accordance with the characteristics and complexity of the problem [10]. Regression problems can be solved using different types of networks: multilayer perceptron, linear network, radial basis function and generalized regression network.

We based on a number of criteria for choosing a neural network architecture:

- Hardware limitations.
- If a more complex architecture shows similar results than a simpler one, then the choice is made in favor of a simpler one.

The recommendations of the developers of libraries for neural networks used in the developed program (TensorFlow, Keras) were also taken into account. The basic architecture model will be a multilayer perceptron. The main feature of the architecture is associated with the fact that the program uses a large number of hidden layers in order to reduce the number of elements in them. This principle is at the heart of deep learning.

One of the important advantages of the chosen model is that it will be able to process a large amount of data quickly enough, which for other models could become a problem faced by companies that are engaged in the purchase and retail of goods in huge quantities and over a long period.

Two hidden layers are justified by the fact that the developed product uses the non-linear activation function ReLu. Function mathematical notation:

$$f(x) = \begin{cases} x, & \text{if } x > 0 \\ 0 & \text{otherwise} \end{cases}$$  \hspace{1cm} (1)
Figure 3 shows the architecture of the neural network being developed.

![Neural network architecture](image)

**Figure 3.** Neural network architecture.

The input layer is the 13 factors from Table 1; $\sum$ - adder; F - activator function. Each new layer receives data with adjustments that were made in the previous layer. At the output, we get a forecast.

The activation functions can be different, but for the chosen architecture the non-linear function ReLu will be used, the graph of which is shown in Figure 4.

![ReLu function graph](image)

**Figure 4.** ReLu function graph.

We will calculate the learning error using the formulas for the mean square error $S$ and the mean absolute error $M$:

$$S_n = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}, \quad (2)$$
$$M = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{x_i - y_i}{x_i} \right|. \quad (3)$$

To visually look at the results of a neural network calculation, you need graphs. For this, you can use the MatLab library.

The activation and error counting functions, as well as the architecture, allow you to create a basic neural network for purchasing forecasting for retail enterprises. In the future, it may require modifications.

One of the most important tasks when creating a neural network is to correctly create the structure of the neural network. To do this, you need to make 4 steps:

- Select the activation function.
- Prepare initial data.
• Create a suitable neural network architecture.
• Select the error counting functions.

The main task is to predict the value of a product over a certain period, which is a regression task. Regression analysis is a set of statistical methods for studying the influence of one or more independent variables $X_1, X_2, \ldots, X_i$ on the dependent variable $Y$. The independent variables are otherwise called regressors or predictors, and the dependent variables are criterion variables. The most common type of regression analysis is linear regression, where a linear function is found that, according to certain mathematical criteria, it most closely matches the data. For example, the least squares method calculates a straight line (or hyperplane) whose sum of squares and the data is minimal.

When solving the regression problem, you will have to face the problems of data normalization, because the data will be in different ranges, which will increase their impact on the forecast. To do this, we consider deep neural networks.

Deep learning is understood as the field of machine learning devoted to the construction of nonlinear classification or regression models, the elements of superposition, which describe the corresponding level of data aggregation of features [11, 12]. A deep neural network (DNN) is an artificial neural network (ANN) with multiple layers between the input and output layers [13, 14]. A deep learning neural network aims to exclude the human factor from the forecasting process. Due to its high accuracy and low prediction errors, the neural network has advantages over physical prediction models [15].

3. Forecast quality estimation

To determine the quality of the forecast, different types of analyses are used, we will consider them below.

The most common measures of quality in regression problems are Mean Squared Error (MSE) and Mean Absolute Error (MAE).

The root-mean-square functional penalizes more for large deviations compared to the absolute mean, and therefore is more sensitive to outliers. When using any of these two functionals, it can be useful to analyze which objects make the greatest contribution to the total error - it is possible that an error was made on these objects when calculating features or a target value.

If there is no error, then it needs to be able to determine why there is such a large deviation. To do this, you must use the rules for dividing the product line into groups. To do this, we will use the standard XYZ analysis method.

XYZ analysis will be able to determine which goods should be paid special attention to when forecasting.

XYZ analysis is a tool that allows you to divide the assortment into groups, depending on the stability of sales and fluctuations in demand for products [16]. The purpose of the analysis is to predict the stability of certain objects of study, for example, the stability of sales of certain types of goods, fluctuations in the level of demand, etc.

XYZ analysis is carried out based on the following classification:

• X-parts have consistent and predictable demand patterns without significant fluctuations. They can be formalized, for example, using their small forecast error less than 10% of the real value.
• Y portions have lower forecast accuracy because their demand curve is subject to seasonal fluctuations or trends. The classification can be made based on the forecast error of their time series in about 10-30% of the real value.
• The Z part is characterized by particularly irregular variations. A high forecast error is possible with Z portions.
The use of XYZ analysis will make it possible to say with higher confidence whether it is worth purchasing goods for a retail outlet, based on the data obtained as a result of the neural network forecast.

XYZ analysis is often combined with ABC analysis. ABC analysis allows you to divide a large amount of data, based on their contribution to the profit of a trading enterprise, into three groups. This allows, first, to highlight the positions that are key. Second, we can concentrate on analyzing three groups instead of a large list, and work with positions within groups in a similar way [17]. These products fall into three categories as shown below:

- **Type A** parts include 10-20% of materials, which account for about 70-80% of the total profit. You should pay special attention to it.
- **Type B** parts are fewer valuable goods with a share of about 10-20% of the total assortment of goods and about 20-30% of the total profit of the enterprise.
- **Type C** part makes up the largest share of approximately 60-70% of the total assortment but bear only 5-10% of the total value.

First, an ABC analysis of goods is carried out by the amount of income received or by the amount of goods shipped for the entire accounting period (for example, for a year). Then an XYZ analysis of these products is carried out for the entire period (for example, monthly sales for the year). After that, the results are combined. Combining the two methods will create 9 product groups, which should further improve the limitation on the permissible forecast error.

**4. Conclusion**
Correctly organized wholesale purchases make it possible to form the necessary range of goods for the retail trade network to supply the population, to influence manufacturers of goods in accordance with the requirements of consumer demand, and also ensure the efficient operation of the trade enterprise. To do this, you need to know the methods for determining the quality of the forecast.

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