RAW MATERIALS INVENTORY MODEL APPLIED BY REGIONAL ENTERPRISES OF THE INDUSTRIAL CLUSTER

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Abstract: For the effective functioning of the industrial enterprises and optimization of the production capacities it is necessary to predict the optimum inventory level of a production line on the basis of logistical approaches and studying the demand for products. Studies were conducted using the example of one industrial enterprise from the Udmurt Republic and there was proposed the inventory control model with the help of exponential smoothing and confidence interval.

1 Introduction
In the constantly changing business environment there is a need for implementation of logistical approaches for managing cluster formations. In Russia there is a great interest in clusters as the mechanism of regional development [1-3]. Today there is a growing need for logistic management approach implementation [4]. The formation of the regional industrial cluster in the Udmurt Republic makes it possible to consider federal and regional interests in addressing problems of military-industrial complex, filling idle capacities and preserving employment [5].

2 Technique of inventory control model development applied by the regional industrial cluster
Different resources are needed for the continuous production of innovative products: the metal of certain grade, hard alloy, labour power, electricity and other resources. This involves significant financial cost, because raw materials must be purchased and stored somewhere. Consequently, there is a need for the proper management of raw materials inventory control system, which will help to reduce production costs and release some working capital. There is data on the demand for the enterprise products in 2017-2018 (Table 1, Figure 1).

Table 1 Data on the demand for the products of the regional enterprise belonging to the industrial cluster in the Udmurt Republic

| Date   | 01.2017 | 02.2017 | 03.2017 | 04.2017 | 05.2017 | 06.2017 | 07.2017 | 08.2017 |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|
| Demand volume | 260     | 300     | 290     | 310     | 270     | 250     | 290     | 280     |
| Date   | 09.2017 | 10.2017 | 11.2017 | 12.2017 | 01.2018 | 02.2018 | 03.2018 | 04.2018 |
| Demand volume | 320     | 300     | 280     | 290     | 270     | 280     | 300     | 310     |
| Date   | 05.2018 | 06.2018 | 07.2018 | 08.2018 | 09.2018 | 10.2018 | 11.2018 | 12.2018 |
| Demand volume | 280     | 300     | 270     | 260     | 290     | 310     | 300     | 290     |

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Before developing the control system for raw materials inventory, it is necessary to choose one of the factors determining the volume of raw material stocks, which will be used in the analysis. The main indicator that determines the volume of raw material stocks is the volume of the demand for manufactured products. In our case, the demand can be considered to be a random value.

It should also be noted that not the current level of demand, but its predicted value plays an important role in deciding volume of raw materials stocks. Therefore, it is necessary to predict the volume of the demand for products at least for one period of time ahead, based on the available data on the demand volume for several previous periods.

One of the most popular methods for time series analysis is exponential smoothing (in our case, demand values are linked to the periods of time, which means they can be considered as the time series).

A simple time series model is designed according to the following formula (1):

\[ x_t = b + \varepsilon_t \]  \hspace{1cm} (1)

Where \( b \) - constant and \( \varepsilon_t \) - accidental error.

The \( b \) constant is relatively stable at every period of time, but may also change slowly over time. One of the clear ways to distinguish \( b \) is to use moving average smoothing, in which weights applied to each of the past observations decrease exponentially.

Simple Exponential Smoothing is designed in such a way that weighting factors decrease exponentially, but unlike moving average all past observations are considered.

The formula of Simple Exponential Smoothing is as follows (2):

\[ S_t = aX_t + (1 - a)S_{t-1} \]  \hspace{1cm} (2)

When this formula is calculated recursively, then each new smoothed value (which is also a prediction) is calculated as a weighted average of the current and smoothed time series. It is clear that the result of the smoothing depends on the parameter (alpha). If \( \alpha = 1 \), then the past observations are completely ignored. If \( \alpha = 0 \), then the current observations are ignored. Values of \( \alpha \) between 0 and 1 can show intermediate results. Empirical studies have shown that very often simple exponential smoothing can give a fairly accurate prediction [6].

We will use the software product «Statistica 6» developed by StatSoft Inc. to forecast values of the demand.

We will use values of the demand level in 2017 as the baseline data. Firstly, we will predict the demand value in January 2018. After that, we will have not 12, but 13 values, and we will predict the 14th and so on by the 24th (December 2018). In the future, these data will help us in drawing up a plan for the raw materials purchase. Initial data are shown in Figure 2.
The chart shows that the time series doesn’t have upward trend or down trend, or seasonality, therefore for our prediction we will use exponential smoothing without consideration of trend or seasonality factors.

There are following results made by the program after data entry and doing calculations (Figures 3 and Table 2).


According to the results, a number of past observations is more significant for the prediction than the current value of the indicator ($\alpha = 0.1$). And the most important thing in these results is the predicted value of the demand equal to 287.6853.

In this case, it is about the number of ordered items, and it cannot be a fractional value, therefore, the number 287.6853 needs to be rounded to the whole, thus, the predicted demand value is 288 units. However, this number cannot satisfy us either, since there's a 50% chance that the demand value will exceed 287.6853 and the same chance that it will not.

To fill this knowledge gap we have to produce a confidence interval for the prediction. We will use the 95% confidence interval. This means that there is a 95% probability that the demand value in a future period lies within the interval.

According to the residuals chart data (Figure 4), it can be concluded that the residuals are normally distributed, which allows us to apply «Student's t-Distribution Table» for confidence limit calculating.
The confidence interval for the prediction is calculated as follows (3):

\[ S_{t+1} = S_t \pm t_{\beta, p} S \sqrt{1 + \frac{\alpha}{2 - \alpha}} \] (3)

where:
- \( S_{t+1} \) - predicted value,
- \( S_t \) - latest calculated value,
- \( t_{\beta, p} \) - value from the Student’s table at significance level \( \beta \) and \( p \) degrees of freedom,
- \( p = n-1, n \)-number of observations,
- \( S \) - standard deviation (4),
- \( \alpha \) - smoothing constant.

\[ S = \sqrt{\frac{\sum_{t=1}^{n}(X_t - \bar{X}_n)^2}{n-1}} \] (4)

where:
- \( X_t \) - observing value.

Calculation data for 12 observations are as follows:

\[ S_1 = 287; \]
\[ t = 12; \]
\[ \beta = 0.05; \]
\[ p = 11; \]
\[ t_{\beta, p} = 2.201; \]
\[ S = 21.1. \]

The confidence interval for the prediction:

\[ S_{13} = 287 \pm 2.201 \cdot 21.1 \cdot \sqrt{1 + \frac{0.05}{2 - 0.05}} = 287 \pm 46.9 \]

But since the quantity of products must be a whole number:

\[ S_{13} = 287 \pm 47 \]

For studying application, the model, we will use the data on demand for products in 2017-2018. Provided that 1 billet is needed for every product manufacturing, we can use data of the Table 1 as the level of raw materials costs needed for every product manufacturing in 2017-2018.

Let us calculate the level of raw materials which are required for other months in 2018. The results are shown in Table 3.

| Date    | 01.2018 | 02.2018 | 03.2018 | 04.2018 | 05.2018 | 06.2018 |
|---------|---------|---------|---------|---------|---------|---------|
| Raw materials, pcs. | 305     | 304     | 303     | 304     | 306     | 305     |
| Date    | 07.2018 | 08.2018 | 09.2018 | 10.2018 | 11.2018 | 12.2018 |
| Raw materials, pcs. | 306     | 305     | 304     | 304     | 305     | 305     |

Now, when we have the data on the required volume of raw materials stocks, as well as actual data on the volume of raw materials in the enterprise (Table 4), we can assess the effectiveness of the models under consideration.

| Date    | 01.2018 | 02.2018 | 03.2018 | 04.2018 | 05.2018 | 06.2018 |
|---------|---------|---------|---------|---------|---------|---------|
| Amount of stock | 740     | 850     | 1090    | 790     | 480     | 950     |
| Date    | 07.2018 | 08.2018 | 09.2018 | 10.2018 | 11.2018 | 12.2018 |
| Amount of stock | 870     | 780     | 720     | 990     | 980     | 900     |

Table 5 shows actual data on the raw materials stocks replenishment at the enterprise in 2018.

On the whole, in 2018 the company purchased 3,330 units of raw materials.

Let us consider how would the structure of the replenishment of raw materials stocks look like, if the enterprise applied cost prediction model on the basis of exponential smoothing (Table 6).

If the enterprise applied this model, then in 2018 they would have purchased 2758 units of raw materials, and the demand would be satisfied. And finally, Table 7 shows the data on the structure of the raw materials stocks replenishment when using Brown's Exponential Smoothing model.

Negative values in the “Residuals” column indicate the level of unmet need for raw materials.

If the enterprise used this model, then 2723 units of raw materials would have been purchased in 2018, while in April and October the company would not have been able to meet the demand due to the fact that the predicted level of the demand for the products (raw materials costs) happened to be less than the actual.
### Table 5 The structure of the raw materials stocks replenishment

| Date     | Inventory at the beginning of the month | Purchase | Actual expenses | Residuals |
|----------|-----------------------------------------|----------|-----------------|-----------|
| 01.2018  | 740                                     | 380      | 270             | 850       |
| 02.2018  | 850                                     | 520      | 280             | 1090      |
| 03.2018  | 1090                                    | 0        | 300             | 790       |
| 04.2018  | 790                                     | 0        | 310             | 480       |
| 05.2018  | 480                                     | 750      | 280             | 950       |
| 06.2018  | 950                                     | 220      | 300             | 870       |
| 07.2018  | 870                                     | 180      | 270             | 780       |
| 08.2018  | 780                                     | 200      | 260             | 720       |
| 09.2018  | 720                                     | 560      | 290             | 990       |
| 10.2018  | 990                                     | 300      | 310             | 980       |
| 11.2018  | 980                                     | 220      | 300             | 900       |
| 12.2018  | 900                                     | 0        | 290             | 690       |

### Table 6 The results of applying cost prediction model on the basis of exponential smoothing

| Date     | Inventory at the beginning of the month | Cost prediction | Purchase | Actual expenses | Residuals |
|----------|-----------------------------------------|-----------------|----------|-----------------|-----------|
| 01.2018  | 740                                     | 334             | 0        | 270             | 470       |
| 02.2018  | 470                                     | 333             | 0        | 280             | 190       |
| 03.2018  | 190                                     | 329             | 139      | 300             | 29        |
| 04.2018  | 29                                      | 328             | 299      | 310             | 18        |
| 05.2018  | 18                                      | 330             | 312      | 280             | 50        |
| 06.2018  | 50                                      | 331             | 281      | 300             | 31        |
| 07.2018  | 31                                      | 329             | 298      | 270             | 59        |
| 08.2018  | 59                                      | 330             | 271      | 260             | 70        |
| 09.2018  | 70                                      | 330             | 260      | 290             | 40        |
| 10.2018  | 40                                      | 326             | 286      | 310             | 16        |
| 11.2018  | 16                                      | 326             | 310      | 300             | 26        |
| 12.2018  | 26                                      | 328             | 302      | 290             | 38        |

### Table 7 The data on the structure of the raw materials stocks replenishment when using Brown’s Exponential Smoothing model

| Date     | Inventory at the beginning of the month | Cost prediction | Purchase | Actual expenses | Residuals |
|----------|-----------------------------------------|-----------------|----------|-----------------|-----------|
| 01.2018  | 740                                     | 305             | 0        | 270             | 470       |
| 02.2018  | 470                                     | 304             | 0        | 280             | 190       |
| 03.2018  | 190                                     | 303             | 113      | 300             | 3         |
| 04.2018  | 3                                       | 304             | 301      | 310             | -6        |
| 05.2018  | 0                                       | 306             | 306      | 280             | 26        |
| 06.2018  | 26                                      | 305             | 279      | 300             | 5         |
| 07.2018  | 5                                       | 306             | 301      | 270             | 36        |
| 08.2018  | 36                                      | 305             | 269      | 260             | 45        |
| 09.2018  | 45                                      | 304             | 259      | 290             | 14        |
| 10.2018  | 14                                      | 304             | 290      | 310             | -6        |
| 11.2018  | 0                                       | 305             | 305      | 300             | 5         |
| 12.2018  | 5                                       | 305             | 300      | 290             | 15        |
3 Conclusion

According to the results of calculations, the model developed on the basis of logistic approaches leads to cost reduction, prevents the possibility of unmet demand, which in the future can lead to a decrease in the number of customers, and that will reduce the profit of the regional industrial cluster in the Udmurt Republic.

Therefore, when developing the inventory control structure in the production of innovative products by enterprises of the regional industrial cluster in the Udmurt Republic, we should use the model which is based on predictions with the applying of exponential smoothing and confidence intervals.

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