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Creation of forecasting information system for delivery of materials in organization

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ABSTRACT

Previous studies have established that the timely supply of material means (MM) can be provided on the basis of diagnostics and / or predictive assessments of the state of technical systems (TS). In this regard, taking into account the operating conditions and the service life of equipment for various purposes, the cost of its repair or manufacturing of parts using structural materials, it is urgent to create forecasting information system (FIS) of needs in MM TS organizations.

Based on the foregoing, using FIS, appropriate MM applications can be generated to restore the operability of technical systems operated by organizations. To obtain timely information on the supply of FIS MM, which allows us to show the dynamics of changes in their condition indicators based on monitoring the technical condition of equipment for the period from 2014 to 2019 (the presence of all types of equipment, the number of faulty and decommissioned equipment, the need for spare parts). The decomposition of the FIS for deliveries of MS includes six modules that allow you to determine: forecasting the state of equipment for the next month, forecasting the number of faulty or decommissioned equipment, forecasting indicators of malfunctions of technical equipment, forecasting the demand for MM and specific spare parts, forecasting seasonal fluctuations in the operational state of the TS. Based on the monitoring of all types of equipment for a specified period of time, forecast indicators were determined, taking into account which applications for the supply of MM were prepared. The materials for this article have been prepared as part of the scientific project No. A05135518.

Key words : material means, information system, forecasting, monitoring, management, technology, organization

1. INTRODUCTION

Timely delivery of MM is provided on the basis of forecast estimates of the technical condition of the equipment and / or diagnostic technology according to the criterion of the value of information [1,2].

All this in the future allows for the early formation of application MM in order to quickly restore the TS to working capacity in operating organizations. To create an information system that provides forecasting of the state of technology in the organization, it is necessary to create a mathematical model that would provide the necessary congruency, that is, ensure the degree of compliance of the model with real data on which it is built and would be a sufficient condition for a successful forecast. In addition, it should be emphasized that when creating a mathematical model for forecasting, stochastic models are used, since as a result of monitoring the state of technology in the organization, we are dealing with random variables and events for this reason it is almost never possible to accurately predict the future values of a series, even if we know the true data generation model [3,4]. In this regard, the prediction error in such models always exists, and these errors can accumulate in the process of dynamic forecasting. Such errors arising from the data collection process itself are also supplemented with errors related to ignorance of the essence of the data generation process and, as a result, are forced to be used for forecasting purposes in a stochastic model that is built on the basis of a particular economic theory, earlier similar studies and character traits available to the researcher of statistical data [5].

2. MATERIALS AND METHODS

Analysis of the technical condition of equipment in the organization

In accordance with the goal of creating FISs, a methodology for monitoring the technical condition of vehicles in the organization's structural divisions was previously developed, on the basis of which insufficient security has now been established: machine maintenance points - 12%, repair shops - 8% and specialized technical service stations - by 17%.

For all structural divisions of the organization, from 2014 to 2019, the following indicators were considered during the monitoring process when constructing the mathematical model (see Figure 1):

- total availability of equipment, pcs.;
- number of faulty equipment, pcs.;

- number of decommissioned equipment, pcs.;
- % inoperative equipment of its total amount;
- existing need for spare parts pcs.

An analysis of special equipment in the structural divisions of the organization shows that in 2019 compared to 2017, it decreased from 3885 to 3614 units, i.e. by 271 units or by 7.0%. The given reduction in the number of special equipment (SE) occurred due to the impossibility of restoring units, assemblies or even parts using its own repair and technical base. In addition, with the help of monitoring, data were obtained that were used to analyze the organization's technical base, on the basis of which recommendations were developed for its improvement and the creation of specialized maintenance and repair sites (SM and R), and it was also established that there was a significant need k_{nom} for structural units of the organization in various types of SE (see Figure 2).

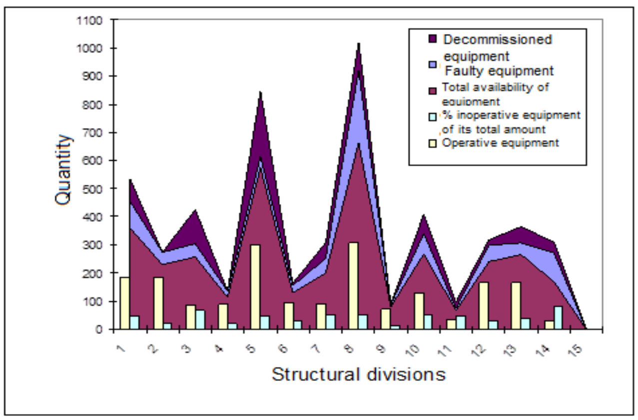


Figure 1: The state of equipment in the structural divisions of the organization

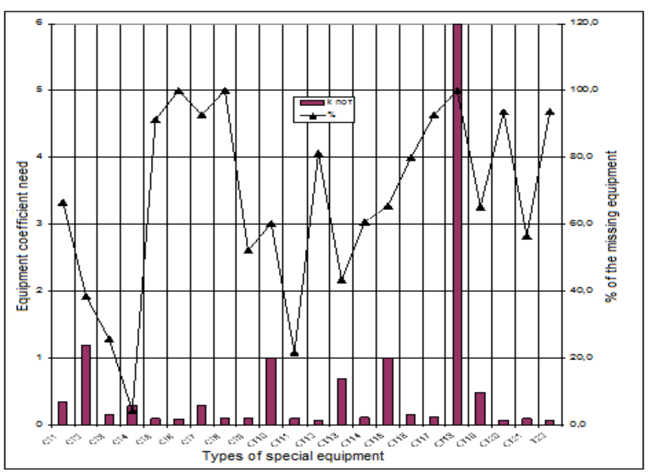


Figure 2: Coefficient values k_{nom} and% of the missing special equipment in the organization

To maintain the special equipment in good condition, and on this basis the successful completion of the planned types of work, the existing repair base of the organization was reorganized, which was restructured on a new technological, organizational, and economic basis.

Taking into account the principles of continuity with the technology of mechanical engineering, specialized sections have been designed that allow, taking into account the peculiarities of the repair production, various types of work related to the repair or manufacture of spare parts and including:

1) analysis of the range of parts manufactured and repaired at this specialized site and their defects;
2) development of technological processes for their restoration and manufacture;
3) design and manufacturing of technological equipment for the developed technological processes and non-standard repair equipment;
4) design of specialized areas for the restoration and manufacture of spare parts on the existing areas of repair shops of structural units of the organization.

Based on the monitoring, systematic issues were considered in forecasting the supply of MM, which implies compliance with the requirements for the interconnectedness and subordination of the object, background and forecasting elements [7]. The main requirements for forecasting are:

- consistency in forecasting the supply of MM means the need to coordinate search and regulatory forecasts of various indicators and different time periods for their availability;
- the variance in forecasting the MM indicates the requirement to develop various forecast options that take into account seasonal variations in the state of technology;
- continuity makes it necessary to regularly perform timely adjustment of the forecast as new information about the forecasting object arrives;
- verifiability means the need for reliability, accuracy and validity of the forecast.

All of these requirements were taken into account in the process of developing the required forecast types when creating FIS MM.

3. RESULTS AND DISCUSSION

Development of a forecasting information system for supplies of material assets

To create an algorithm for the operation of FIS, the following statistical forecasting methods were previously determined [8]:

1) Moving average extrapolation - can be used for the purposes of short-term forecasting of TS malfunctions:

$$y = \frac{\sum y_i}{n}, \quad (1)$$

where $\sum y_i$ - volume of equipment malfunctions;

n – a period of time, the number of « n »values for calculating the moving average is selected depending on how important the old values of the indicator in comparison with the new ones.

2) To determine the forecast by extrapolation from the current state of faults or write-offs of the vehicle, it is necessary to determine its average annual changes over the past years and extrapolate to future periods.

$$\bar{k} = \sqrt[n-1]{\frac{y_n}{y_i}}, \quad (2)$$

where $\bar{k}$ - average annual changes;
n – number of years;
y_n - number of TS malfunctions in the reporting year;
y_i - number of TS malfunctions in the base year;

3) In the module "Prediction of equipment malfunctions for the next month", it is possible to calculate the average forecast error, which is calculated by the following formula:

$$\mu = \pm\sqrt{\frac{\delta^2}{n}}, \quad (3)$$

where μ - average error;
δ - dispersion determined by the formula:

$$\delta^2 = \frac{\sum(x - \bar{x})^2}{n}, \quad (4)$$

4) Prediction by linear regression is one of the most widely used methods of statistical forecasting. In this regard, we have the following expression:

$$y = a + b \cdot x, \quad (5)$$

where y – number of malfunctions or decommissioned TS during the year;
x – years;
a – parameter characterizing the influence of the main parameters on emerging TS malfunctions;
b – parameter characterizing the influence of auxiliary factors on the occurring malfunctions in the TS.

To find the parameters a and *b*, it is necessary to solve the following system of equations:

$$\begin{cases} a \cdot n + b \cdot \sum x = \sum y \\ a \cdot \sum x + b \cdot \sum x^2 = \sum x \cdot y \end{cases}, \quad (6)$$

5) Prediction of the occurrence of TS failures based on seasonal fluctuations is a statistical forecast method for seasonal fluctuations, which is based on their extrapolation, that is, on the assumption that the parameters of seasonal fluctuations are stored until the end of the forecast period.

$$I_s = (y_i / y) * 100\%, \quad (7)$$

where I_s - seasonality index;
y_i - level of changes in TS malfunctions for months is determined by the formula;
y – level of TS malfunctions in year.

The average seasonality indices calculated in this way can be used as the basis for planning the availability of MM applications to ensure timely operation of the TS in the structural divisions of the organization for the next year.

The proposed method, based on predictive assessments of the condition of the TS, can significantly reduce the time and reduce the amount of labor required for repairs, increase the coefficient of technical readiness and create conditions for more efficient use of each type of equipment, taking into account the degree of wear and timely replacement of faulty components, assemblies and / or parts for technical repair or maintenance. To apply this method in an organization, it is necessary to create a revolving fund for the MM, formed from new or repaired spare parts, which is formed on the basis of forecast estimates obtained using FIS.

It should be noted that in addition to this, there are recommendations according to which, the need for a revolving fund of spare parts for service maintenance is determined from the expression [9]:

$$П = К \cdot \frac{A \cdot M \cdot B \cdot T_П}{365 \cdot T_У}, \quad (8)$$

where *К* – coefficient that takes into account the possibility of a deviation in time of turnover and the failure of spare parts, K = 1-1.3;
A – number of identical spare parts installed on one TS;
M – number of types of equipment in which this spare part is used;
B – spare parts turnover time, taking into account their loading, unloading and delivery from a specialized enterprise for repair at the factory, number of days
$T_П$ – planned operating time of the TS during the year, the number of days;
$T_У$ – service life of a particular part or unit, the number of days.

In the process of restoring the performance of the TS, services that perform the corresponding functional duties, it is necessary to carry out the planning of the MM consumption. In this case, the MM consumption for maintenance and repair is determined in accordance with the formula [10]:

$$Q = \lambda \cdot H_i \cdot [\Sigma R_к + \alpha \cdot \Sigma R_с + \beta \cdot \Sigma R_м], \quad (9)$$

where λ - coefficient taking into account the consumption of the main MM for maintenance, λ =1,15;
H_i – consumption rate of MM per one overhaul per one repair unit;
α, β - coefficients characterizing the relationship between the number of MM spent on average and overhauls, α =0,6 и β =0,2;
$\Sigma R_к, \Sigma R_с, \Sigma R_м$ - total number of TS units annually repaired for major, medium, and minor repairs.

Based on the above provisions, an information system (IS)

"Forecasting the state of technical systems in the organization" was developed, designed to manage the process of preparing applications for MMs used to restore the operability of TS in structural units of the organization, to reduce the risks of making managerial decisions by considering various forecast options . This IS is used when performing the following types of forecasting:

– condition of equipment for the next month and data on its possible malfunctions;

– number of faulty and / or decommissioned equipment;

– indicators of malfunctions with an increase in the number of equipment;

– demand for material resources;

– needs for spare parts;

– seasonal fluctuations in the technical condition of equipment.

The IS interface complies with the requirements of existing standards, has a help system, and does not require the end user to use in-depth knowledge of mathematical statistics and forecasting when using this software product, since the software product algorithm allows you to analyze the entered time series of the state values of the equipment in the structural units of the organization and generate the corresponding forecast indicators. The block diagram of the IS "Forecasting the state of technical systems in the organization" includes eight modules. After starting the IS, the main program window opens with a menu, in the line of which there are two tabs “Forecast” and “Help”. Using the “Forecast” menu, you can select any of the six forecasting modules presented above from B to G (Figure 3).

Modules B, C, D, E, and F make it possible to calculate forecasts for the short-term and long-term periods of the technical condition of the equipment, and display the obtained forecasting results in the software product window. Module G is intended only for calculating forecast estimates of seasonal fluctuations in the technical state of technology (Figures 4,5; table 1).

The results of such predictive calculations are presented in tabular and graphical form. All obtained predictive estimates are saved in a file, and the results obtained in tabular form can be printed.

Table 1: Forecasting of seasonal fluctuations in the technical condition of equipment

Forecasting of seasonal fluctuations in the technical condition of equipment				
Seasonal fluctuations				
	1st year (pcs.)	**2nd year (pcs.)**	**3rd year (pcs.)**	**Average seasonality index**
January	12	4	7	47%
February	4	8	15	55.15%
March	23	16	28	136.6%
April	17	9	19	91.91%
May	9	11	13	67.4%
June	31	25	28	171.6%
July	22	29	21	147.1%
August	18	19	15	106%
September	14	18	17	99.88%
October	19	23	16	118.3%
November	8	11	14	67.4%
December	16	13	16	91.91%
Total	193	186	209	

For the implementation of forecast models, it is necessary not only to have timely and accurate information about the current state of technology, but also to be able to comprehend, draw conclusions and effectively translate it into managerial decisions on the formation of applications for the supply of MM in the organization.

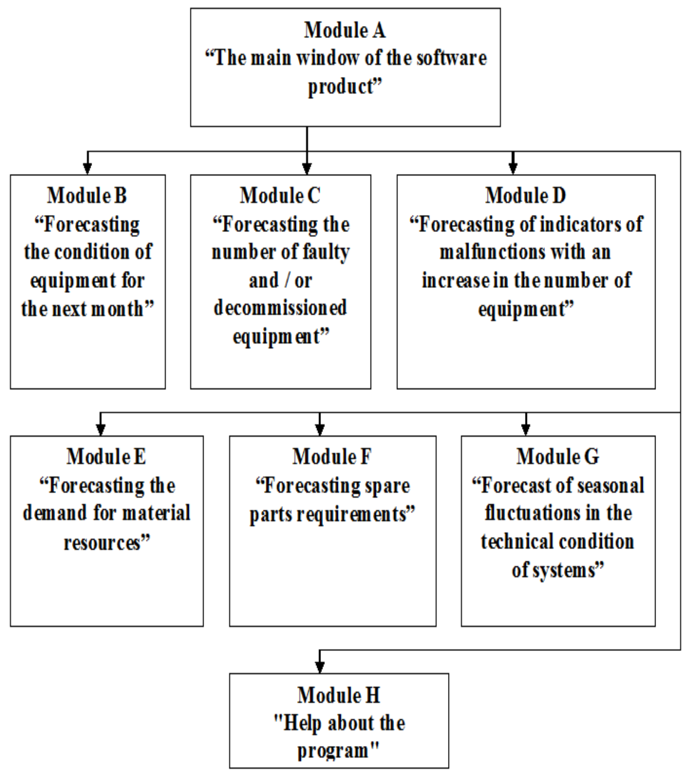
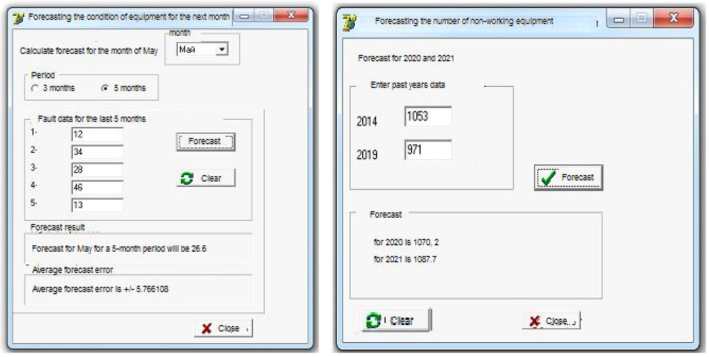


Figure 3: IS decomposition "Forecasting the state of technical systems in the organization"

The implementation of any goal in the process of activity of the structural units of the organization is always associated with the problem of choosing from the available forecast alternatives the most optimal, which introduces an element of uncertainty into the forecast model. Reducing uncertainty is ensured through the use of information previously obtained during monitoring. The verification of the adequacy of the forecasting model is carried out using formal statistical criteria. Therefore, it should be carried out only in the presence of the correct statistical parameters of the forecasting object and the model itself. If sometimes such estimates are not available, then a comparison is carried out for individual properties of the original and model. In this case, the truth of the implemented functions must be checked first, then the truth of the structure, and then the truth of the parameter values achieved in this case [11].



a) b)

Figure 4: Forecasting for the short and long periods of the technical condition of the equipment: a) - forecasting the condition of equipment for the next month; b) - forecasting the number of non-working equipment

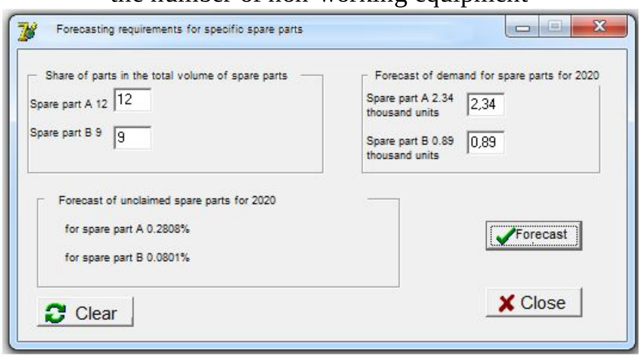


Figure 5: Forecasting requirements for specific spare parts

Using the developed FIS for deliveries of MM and the technical condition of the equipment, forecast data on previously obtained indicators for 2019 were fulfilled, which were then compared with the actually available parameters of the technical condition of the equipment on the balance sheet in the structural divisions of the organization. The largest discrepancy in data on its availability was 7.6%, and in the number of decommissioned equipment - 7.9%. The average error for all indicators did not exceed 6.03% (Figure 6).

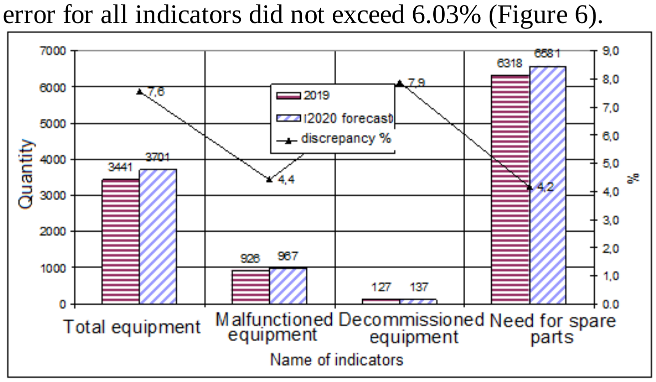


Figure 6: Comparative analysis of indicators of the technical condition of equipment for 2019 in the organization and forecasting estimates obtained by FIS

Features of inventory management of structural units of the organization

In order to deliver MM in a timely manner to ensure the operability of equipment, a system for managing their reserves is required, which is formed on the basis of the FIS state of technical equipment in the organization. The block diagram of the organization's inventory management system is shown in Figure 7.

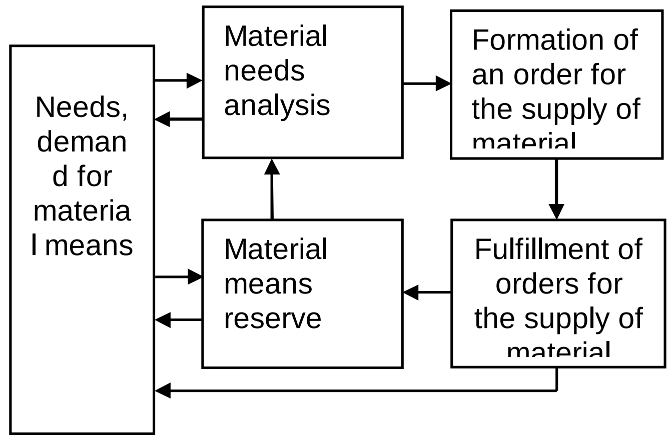


Figure 7: Block diagram of the stocks of material means management system

In order to ensure rational supplies of material resources, we use the Generalized Reduced Gradient (GRG2) nonlinear optimization algorithm.

In accordance with the foregoing, a search was made for the most rational route for the supply of MM using the example of spare parts for equipment equipped with hydraulic equipment manufactured at factories A, B, C, D. In the considered solution to the transport problem, the minimum costs for transporting hydraulic equipment sets to the specified structural organizational units, while these costs amounted to 907 conventional units, with an appropriate distribution of supplies of spare parts from manufacturers (Table 2).

Table 2: Results of solving the transport problem

Initial data							
Name of interacting enterprises	Consumers						Suppliers stocks
	Organization structural divisions	1	2	3	4	5	
Suppliers	A	94	546	224	269	1185	350
	B	94	546	224	269	1185	280
	C	94	546	224	269	1185	240
	D	159	751	331	166	1618	190
Consumer needs		245	179	187	363	86	1060
Estimated data							

Suppliers	A	0	0	177	173	0	350
	B	245	35	0	0	0	280
	C	0	144	10	0	86	240
	D	0	0	0	190	0	190
Consumer needs		245	179	187	363	86	
Total cost of transportation, conventional units							907

The effect of the introduction of FIS to ensure MM is expressed in a decrease in the total cost of resources used and, in general, an increase in profitability from the organization. Estimated economic efficiency from the use of ISP by improving the system of maintenance and R equipment based on the targeted formation of one type of spare parts sets for the organization is 6561.45 conventional units.

5. CONCLUSION

Based on predictive assessments of the condition of the TS to ensure their repair due to the timely supply of MM, an effective tool is their FIS.

For this purpose, a technique was previously developed for monitoring the technical condition of the TS in the structural units of the organization, within which indicators such as the state of the equipment for the next month and data on its possible malfunctions, the number of malfunctioning and / or decommissioned equipment, information on malfunctions with an increase in the number of equipment were considered demand for material resources, needs for spare parts, seasonal fluctuations in the technical condition of equipment.

According to the monitoring results, the coefficient of demand for equipment and% of the missing equipment in the organization were established.

In the process of developing the FIS for deliveries of MM, the requirements for forecasting were preliminarily formulated and statistical forecasting methods were determined for various variants of the technical condition of the equipment.

In order to verify the adequacy of the functioning of the FIS for the supply of MM, the predicted data on the previously obtained indicators for 2019 were fulfilled. The largest discrepancy in the data on its availability was 7.6%, and on the number of decommissioned equipment - 7.9%. The average error for all indicators did not exceed 6.03%.

To ensure the structural units of the organization's MM, a block diagram of the MM inventory management system was developed, within the framework of which the transportation problem was solved with the establishment of minimum costs for the supply of hydraulic equipment sets from manufacturers to the organization's structural units.

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