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THE OPTIMAL PLAN FOR THE PURCHASE OF SPARE PARTS FOR PRODUCTION LINES

Production lines producing consumer goods consist of a large number of parts, some of which are used in several machines. Stopping due to failure of any spare part of any of the machine's line means the termination of production.

The termination of the production line is a lack of income for the product sold. Therefore, it is necessary to make spare parts, in order to replace them immediately in case of failure. The larger such stocks, the worse the situation with the turnover of capital, and therefore, with profits. Spare parts stocks need to be optimized.

In most cases, inventory optimization is done using either the Wilson model or the statistical model. In [1] it was shown that the use of both models for one object gives a difference several times, therefore, the use of these models is problematic.

For the solution of this problem, the position on the theory of reliability was used. Assume that there are n devices that must work simultaneously over time t. The probability that any of them will fail to do this term is p (the same for all devices, and devices are denied independently of each other). How will the likelihood of a system fail-safe work, if in it, in addition to the main devices, there are still m a reserve, located in a loaded state (that is, in the same mode, in which the main one). The refusal is still considered the transition of the system to such a state, when in it the number of capable devices is less n. The sought probability is [2]

$$P_n(m) = \sum_{i=0}^{m} C_{m+n}^{n+i} p^{m+i} (1-p)^{m-i} \quad , \qquad (1)$$

To obtain a smooth function, the experiment planning method was used [3]. For a trifactorial experiment, a plan was presented, presented in Table. 1, where both relative and absolute values of factors are presented.

Table 1

Relative and absolute values of the factors of the experiment

Relative values			Absolute values		
n	*m*	*p*	*n*	*m*	*p*
-1	-1	-1	9	2	0,146389
1	-1	-1	19	4	0,146389
-1	1	-1	9	2	0,146389
1	1	-1	19	4	0,146389
-1	-1	1	9	2	0,213611
1	-1	1	19	4	0,213611
-1	1	1	9	2	0,213611
1	1	1	19	4	0,213611
-1,44	0	0	1	3	0,18
1,44	0	0	29	3	0,18
0	-1,44	0	14	1	0,18
0	1,44	0	14	5	0,18
0	0	-1,44	14	3	0,07
0	0	1,44	14	3	0,29

The formula (1) calculated the probability of failure-free operation of spare parts, and then, applying the method of least squares, there was a dependence of the form

$$P(n,m,p) = a_0 + \sum_{i=1}^{3}(a_i x_i + a_{i+3}x_i^2) + x_1(a_7 x_2 + a_8 x_3) + \\ + a_9 x_2 x_3 + a_{10} x_1 x_2 x_3 \quad , \quad (2)$$

where, x_1, x_2, x_3 – in accordance *n, m, p*; $a_0 \ldots a_{10}$ – coefficients of the model. The calculation of the coefficient was made using the application Regression of Microsoft Excel spreadsheets and the following exact dependence ($R^2 = 1$) was obtained.

$$P(n,m,p) = 86{,}7681605124964 - 2{,}84833424436937n - 29{,}108090005352m - \\ -263{,}661359237691p + 0{,}502980497238123nm - 11{,}8302415352799np + \\ +3{,}18474557260924nmp + 0{,}0776912809148127n^2 + 2{,}28310029726217m^2 + \\ +899{,}888428544503p^2$$

(3)

Dependence (3) can be used for the specified in the table. 1 number of main $n = [1, 29]$ and spare parts $m = [1, 5]$, which have probability of failure-free operation $p = [0.07; 0.29]$. The probability data was taken from the information in the real enterprise by calculating how often parts of the product line fail during the month.

Let the number of types of defective parts make D. Then the probability of failure-free operation of the production line can be found as a product of the failure-free operation of each of the parts, provided that the company has their additional stock

$$P_L = \prod_{j=1}^{D} P(n_j, m_j, p_j) \tag{4}$$

where $P(n_j, m_j, p_j)$ is based on formula (3).

We denote how REV earnings per month from the uninterrupted work of the production line, and as $PROF$ – respectively, the profit from the uninterrupted operation of the line. From there, taking into account (4), it can be written that the total revenue from the work of the line will be

$$REV_{TOTAL} = P_L REV - PROF(1 - P_L) \tag{5}$$

Obviously, the total profit should be reduced by the cost of spare parts, which should be kept in case of failure of operating parts, multiplied by the probability that n_j of identical parts will work smoothly during the month

$$CSP = \sum_{j=1}^{D} c_j m_j \left(1 - \prod_{i=1}^{n_j} (1 - p_j)\right) \tag{6}$$

where c_j – the cost of the j-th spare part.

By combining (5) and (6) we get a target function that should strive for a maximum

$$REV_{TOTAL} = P_L REV - PROF(1 - P_L) - \\ - \sum_{j=1}^{D} c_j m_j \left(1 - \prod_{i=1}^{n_j} (1 - p_j) \right) \to \max \quad (7)$$

The limitation for this task will be a requirement $0 \le m_j \le 5, (1 \le j \le D)$

These same parameters will be variable factors in the optimization problem, which makes it a linear problem of mathematical programming, which can be solved by a simplex method.

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