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Optimization of the system of management of stores of the car service with the help of imitation simulation

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Abstract. The purpose of simulation is described, the theoretical foundations of the simulation model of inventory management at the service station with its scheme are given. The criterial function of delays, which is the main one in the management of stocks at the service station, is given, the analysis of the influence of the controlled parameters of the model on the criterial function is carried out. The algorithm of search optimization with integration into the simulation model is resulted and optimal parameters of the stock level.

1 Introduction

Currently, in accordance with the supplier's (manufacturer's) interest in the implementation to ensure its plans for the production of spare parts, the car service stations (CSS) must maintain significant stocks of spare parts in their warehouses, as shown by the research of Rustenburg and van Houtum [1]. At the same time, the technical necessity and economic feasibility of keeping such a quantity of stocks in the warehouse have not been studied and are not substantiated. Replenishment of the warehouse occurs usually every two weeks and, due to the lower consumption of spare parts of car service stations (CSS), rather than from the store that sells them, simultaneously with the greater responsibility of the CSS for their availability, since the lack of spare parts calls into question the efficiency of the operation station, which is reflected in the studies of Cheng and Tsao [2], as well as Martin [3]. For CSS, the definition of liquid spare parts and their optimal reserves is of particular importance, as noted in the studies Cheng and Tsao [2].

As it is known from Graves's and Willems's research [4], the size of the stock, as one of the characteristics of the inventory management system, is influenced by a number of factors: the size and frequency of supplies, the number of cars operated in the region, the conditions and the intensity of their operation, and much more. A prerequisite for scientifically based inventory management is the scientifically based forecasting of the flow and the needs of spare parts for each particular car service taking into account objectively acting factors, as described in the studies of Wenbin Wang, Aris A. Syntetos [5], and Eaves with Kingsman [6].

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With the existing study of the issue of forecasting the use of spare parts, the influence of the factors affecting the size of stocks in the service stations serving the cars of the region is not sufficiently taken into account the research work of C.Ronzoni, A.Ferrara, and A.Grassi [7]. Existing electronic enterprise management systems, in particular "1C: Enterprise", allow you to make predictions based on the simplest models.

In view of the foregoing, the purpose of the work was determined: the development of an effective method, taking into account the interaction of factors with the consumption of spare parts, and the development of a model taking into account this influence.

2 Material and methods

Setting research objectives is to develop:

• simulation model of inventory management

• description and analysis of the effect on the criterial function of the monitored parameters of the model;

• Integration into the model of the algorithm of search optimization;

• determination of the level of optimal reserves.

The relevance of the study is determined by the need to increase the competitiveness of the service center, in which the optimization of warehouse costs, the reduction of the "necrotic capital" in the form of illiquid stocks of spare parts becomes especially important.

3 Theory and calculation

Due to the influence of many factors, optimization of inventory management is possible when analyzing the impact on its parameters through simulation.

To construct a simulation model of inventory management, one of the main tasks is modeling the input flow of applications for individual parts and components that must correspond with the results obtained on the basis of a statistical analysis of the functioning of real repair service stations, according to a study by Dieter [8].

Currently, the process of simulating the flow of requirements for spare parts is represented by a moving average model according to the dealer center "Rolf Center". For example, the stuck part of the bumper amplifier (REINFORCEMENT, FR BUMPER) is selected.

It is reduced to a single parametric form, which forms a generalized model of inventory management.

List of managed parameters:

• OctMinZ - the minimum amount of stocks for the formation of an order for the supply of spare parts;

• OctMaxZ - the maximum amount of stocks for the formation of an order for the supply of spare parts;

• Tzak is a variable that specifies the random time for the delivery of spare parts (the initial distribution is uniform over the interval);

• T - planning horizon of the inventory management system, T = 365 days;

• μ - intensity of requests for a particular part μ = 1.2 units / order (order for maintenance or repair);

• s - the price of holding one position per unit of time s = 0.5 rubles / day;

• g - cost of delivery of the party g = 850 rub;

• *h* - penalty for missing parts h = 400 rubles / day (as a penalty, costs are associated with the lack of parts in the warehouse and the need for emergency delivery);

The enlarged flowchart of the algorithm of the single-product inventory management system subprogram (Fig. 1) contains the steps of generating a model range of request volumes, making an order planning decision, monitoring the number of balances in the warehouse, and others.

A series of experiments was performed to estimate the character of the distribution of the criterial function at the values of the parameters:

• Ras - the need for spare parts (μ = 1.2 units / order, the actual consumption per day is the result of multiplying μ by the number of technical impacts per day);

• Pri - time series of receipt of lots;

• Oct - the rest of spare parts in a warehouse;

• SigZak ~ 0 - a sign of the application for supply;

• t - 1 ÷ Tmod = 365 days - model time, etc.

In the process of modeling, the main result is the construction of a selective function of a random temporary volume of stocks for the selected nomenclature of spare parts (Fig. 2).

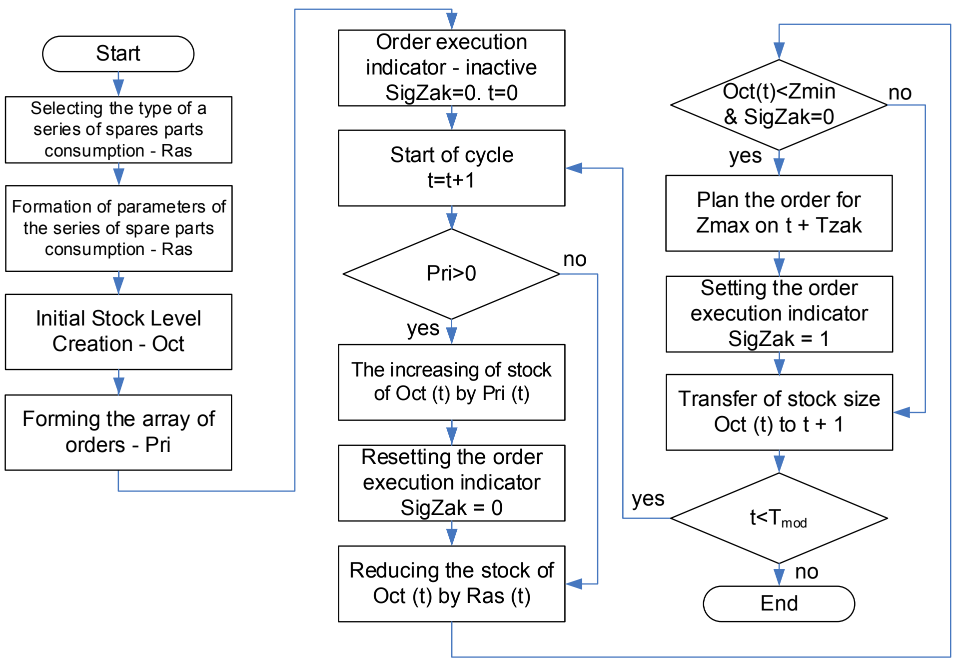

Fig. 1. Enlarged block diagram of the algorithm for the subprogram simulation of a single-product inventory management system.

The scheme of inventory management processes is implemented in the MATLAB program in the developed simulation model of spare parts management.

```
function [Fcrit,Ras,Oct,Pri]=UZf(ParmW);
Tmod=ParmW(1);  % 1 -  Planning horizon
Zmin=ParmW(2);  %  2 - Minimum amount of stocks
ZMax=ParmW(3);   %  3 - Maximum amount of stocks
Tzak=ParmW(4);   %  4 - Time for the delivery of spare parts
s=ParmW(5);           %  5 - The price of holding one position per unit of time
g=ParmW(6);           %  6 - Cost of delivery of the party
h=ParmW(7);           %  7 - Penalty for missing parts
```

```
VR=ParmW(8);       % 8 - Type of time series consumption
mu=ParmW(9);       % 9 - Intensity of requests
% ___________ Formation of working arrays ____________
%Ras=rrr;
if VR==1                          % Parts consumption
  Ras=binornd(10,mu,1,Tmod);
elseif VR==2
  Ras=geornd(mu,1,Tmod);
else
  ParmVR=[Tmod;1;1];
  Ras=SPf_ARI(ParmVR);            % The need for spare parts
end
Pri=zeros(1,Tmod);                % Time series of receipt of lots
Oct=zeros(1,Tmod); Oct(1)=ZMax;   % The rest of spare parts in a warehouse
% ____________________________________________________________
SigZak=0;                         % A sign of the application for supply
for t=1:1:Tmod
    if Pri(t)>0
      Oct(t)=Oct(t)+Pri(t);       % Total balance at the beginning of the day
      SigZak=0;
    end
    Oct(t+1)=Oct(t)-Ras(t);       % Balance at the end of the day
    if Oct(t+1)<Zmin & SigZak==0
        Pri(t+Tzak)=ZMax-Oct(t+1); SigZak=1; % Placing an order
     end
end
% ___________ Cost calculation ____________________________
Fcrit=0;
for t=1:1:Tmod
      if Oct(t)>0
        Fcrit=Fcrit+Oct(t)*s;
      else
        Fcrit=Fcrit-Oct(t)*h;
      end
      if Pri(t)>0
        Fcrit=Fcrit+g;
      end
end
```

In this case, the vector of parameters should be formed:

```
• Parm=[365,  % 1 Tmod  - Planning horizon
   5,  % 2  Zmin  - Minimum amount of stocks
   20,  % 3  Zmax  - Maximum amount of stocks
    3,  % 4  Tzak  -  Time for the delivery of spare parts
    0.5,  % 5  s     -  The price of holding one position per unit of time
    850,  % 6  g     -  Cost of delivery of the party
  400,  % 7  h     -  Penalty for missing parts
    2,  % 8  VR    -  Type of time series consumption
  1.2];  % 9  mu   -  Intensity of requests
```

• A one-time program call is made.

```
[MFcritW, RasO, OctO, PriO]=UZf(Parm);
```

```
OctO=OctO(1, 1:Tmod);
PriO=PriO(1, 1:Tmod);
t=1:1:Tmod;  plot(t, [RasO; OctO; PriO]);
```

A two-tier model represents a single-product model with instantly executed orders for the supply of any volumes. In the case of lack of details, applications are also taken into account. At the same time, when the total stock drops to OctMinZ, then the Q-volume arrives instantly, and the stock becomes OctMaxZ. Total costs represent the amount of costs for storage, delivery and deficit.

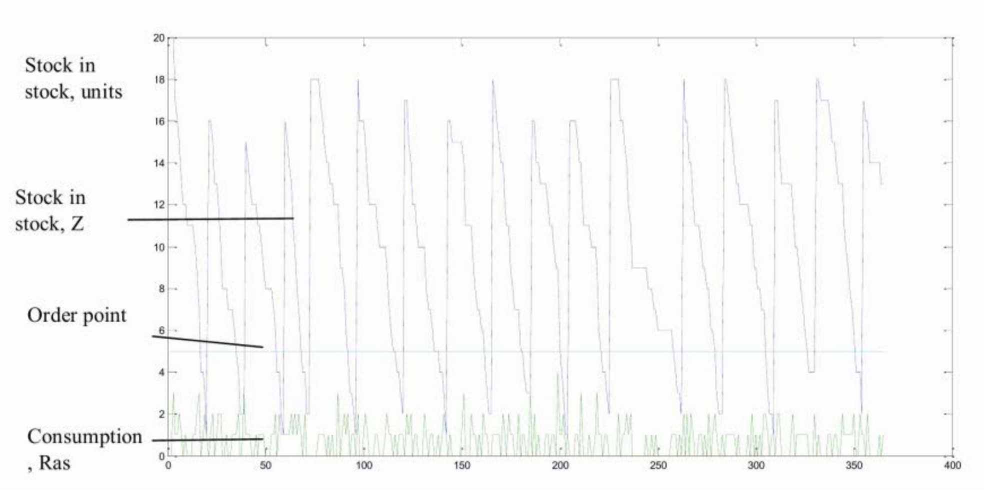

Fig. 2. Selective trajectory for a model without a deficit.

In this case, the average costs at the planning horizon can be represented in the form

$$f_1(T,y)=f_1(y(t)\le t<T)=\frac{1}{T}\left\{s\sum_{t=1}^{T}y_t\chi\left(y_t\ge 0\right)+h\sum_{t=1}^{T}\left|y_t\right|\chi\left(y_t<0\right)+gn\left(T\right)\right\}, \qquad (1)$$

where y (t) represents the level of stocks; $\chi(A)$ is the indicator function of the set A ($y(t)\geq 0\Rightarrow\chi(y(t)\geq 0)=1$; $y(t)<0\Rightarrow\chi(y(t)\geq 0)=0$); s, h, g are the parameters of the model presented above.

The optimization task is to find the values of the lower OctMinZ and the upper OctMaxZ levels, which deliver a minimum of average costs.

The analysis of the influence of the controlled parameters of the model on the criterion cost function (Fig. 3) is carried out to take into account the value of the parameters at other service stations (Costs are per year).

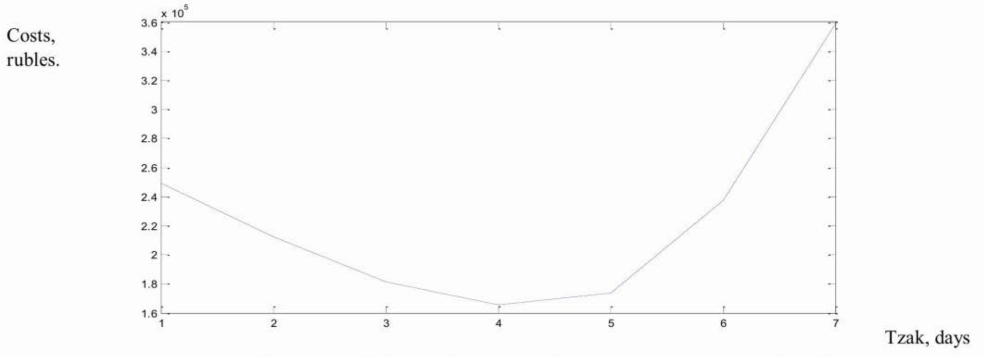

Fig. 3. Influence of the order execution time on costs F (Tzak).

The decision of the problems of the analysis of the behavior of the inventory management system naturally goes into the formulation of optimization tasks by various parameters (maximum delivery volume, order point and others). In this regard, we can not limit ourselves to simulation simulation. It is necessary to use optimization methods, for example, search. In this regard, it is proposed to implement the integration of the simulation model with the algorithms of stochastic approximation. In general, the optimization block solves the problems of a directed enumeration of the model parameters, and the simulation model is used to form the values of the optimization criterion by which the search is realized (Fig. 4).

The purpose of the optimization procedure is to improve the value of the criterion function by selecting the values of the controlled parameters. The use of precise optimization methods is inexpedient due to the impossibility of excluding a random component when calculating the criterion from a selective trajectory of the inventory management process.

To perform the optimization procedure, its algorithm is developed with integration into the model (Fig. 5).

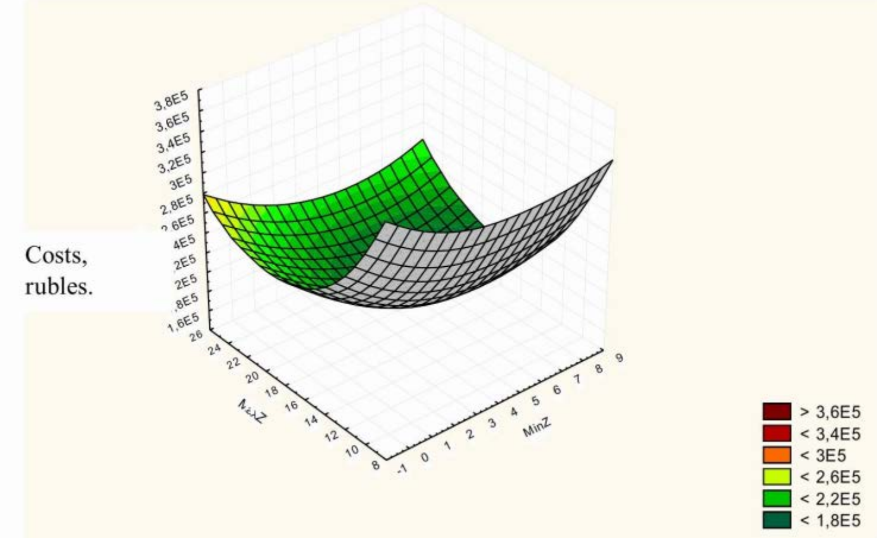

Fig. 4. Optimization by stock size level on stock.

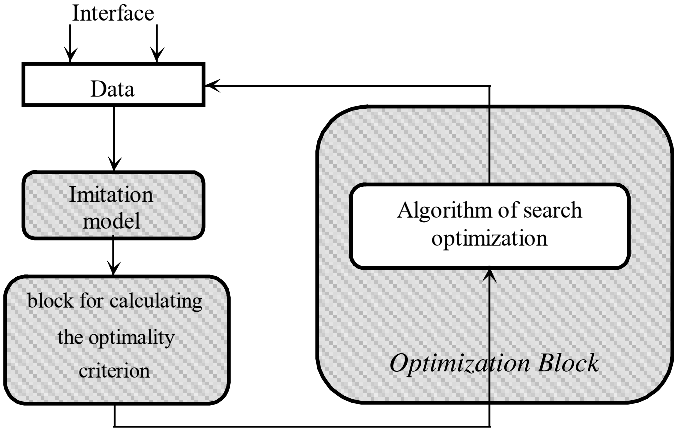

Fig. 5. Integration of the simulation model and algorithm of search optimization.

Within inventory management tasks all controllable parameters are combined into a single parameter vector $\overline{X} = (X_1^k,...,X_N^k)$, and a discrete increment embodiment, the parameter value at each step is determined by the step number is given study Li [9], i.e.

$$\overline{X}^{k+1} = \overline{X}^{k} + \gamma_k \overline{S(X^k)}, \tag{2}$$

In this case, for the increment step γ_K, must be done the follow conditions

$$\sum_{k=1}^{\infty} \gamma_k = \infty; \qquad \sum_{k=1}^{\infty} \gamma_л^2 < \infty; \qquad \gamma_k > 0; \qquad \lim_{k\to\infty} = 0\,, \tag{3}$$

Vector - column $\overline{S(X^k)} = (S_1,...,S_N)$ defines the direction of search based on the analysis of the local area of the studied parameter point. Within the framework of the simulation model algorithm, it is possible to consider different variants of the run, i.e. make a decision to change parameters based on one or more runs of the model on the same parameters. The more runs, the higher the accuracy of the criterion evaluation, the smaller, the lower. However, it is shown that the Robbins-Monroe stochastic approximation algorithm ensures convergence even for sufficiently large variance estimates, which corresponds to running the inventory management model on only one segment of the planning horizon.

For sufficiently large variances, it is proposed to use the sign algorithm, in which the parameter change is realized on the basis of a symmetric plan without a central point

$$\prod = \left[X_n + c_n I_1, X_n - c_n I_1, \; ...X_n + c_n I_M, X_n - c_n I_M\right]^T. \tag{4}$$

and the transition is carried out on the basis of the increment sign:

$$X_{k+1} = X_k + a_k \cdot sign(\Delta Y_k\left(c_k\right)). \tag{5}$$

In general, to analyze the convergence of the algorithm, we use the Lyapunov function ($\forall x$ $\boldsymbol{V}(x) \geq 0$; $\boldsymbol{V}(x^*)=0$), for which it is shown Poznyak [10, 11] that the condition $k\to\infty \Rightarrow MV(x)\to 0$ holds if the relation $\left\|\nabla V\left(x'\right) - \nabla V\left(x''\right)\right\| \leq L \cdot \left\|x' - x''\right\|$ and the distribution $\overline{S}\left(x\right)$ depend only on k and x_k, and the components are independent in this case. There are a number of other conditions, but they are quite rigid in nature purely theoretically, and in practical applications and in our case, the determination of the criterion function of the inventory management system is being carried out.

Thus, under the above conditions, we can speak of the convergence of the sequence X_k to the extremal one with probability 1.

When you run the algorithm, the increment step sequence $\{a_k\}$ and the discretization of the local neighborhood of the point $\{c_k\}$ under study can have a fairly wide range of dependencies. It is proposed to use power-law dependencies:

$$a_k = \frac{a_0}{k^{ap}}; c_k = \frac{c_0}{k^{cp}}\,, \tag{6}$$

In order for these sequences to ensure convergence (that is, they satisfy the convergence conditions [7]), they must satisfy the constraints

$$1^3 ap > 0.75 \, \text{and} \, ap - 0.5 > cp > 1 - ap\,, \tag{7}$$

In the framework of the conducted studies on estimating the convergence rate of the developed Robbins-Monroe algorithm, we used the extension of a quadratic function to the multidimensional case:

$$V(x) = \sum_{i=1}^{N} x_i^2 , \tag{8}$$

and also taking into account the asymmetry of the quadratic form.

In modeling, it was assumed that the generation of selective trajectories of the inventory management process began from the same initial state on independent random sequences, which makes the components $\overline{S}(x)$ independent.

In general, we can say that any finite number of terms of the series does not change its convergence. The analysis showed that for initial values far from the maximum, the rate of convergence at the initial stage of the algorithm is small enough. Therefore, in the initial phase it is suggested to use increased steps or in general a constant.

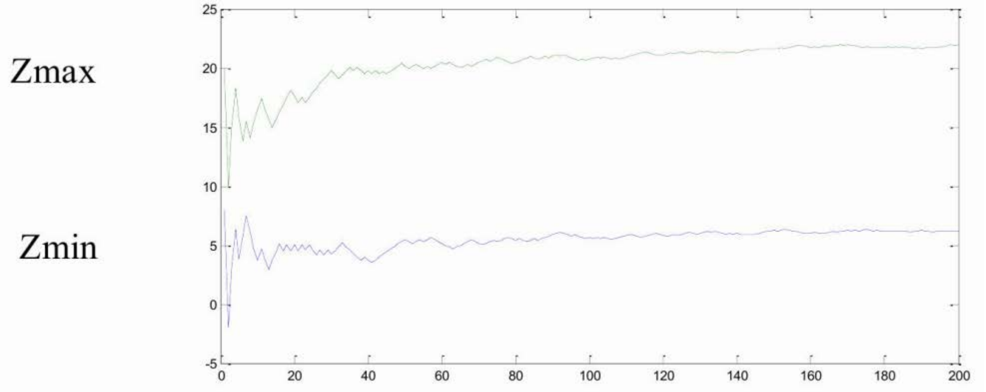

Fig. 6. Carrying out the Kieffer-Wolfowitz procedure in the task of optimizing the inventory management system for two parameters (Zmax and Zmin).

The studies carried out showed rather rapid convergence (Fig. 6). As a result, the developed program is included in the complex of analysis and optimization of the inventory management system.

4 Results

As a result of the conducted researches the model of definition of levels of storage of stocks in a warehouse with procedure of their optimization is developed.

5 Discussion

The developed model makes it possible to optimize the volume of warehouse stocks by the criterion of minimizing the costs of inventory management. This model was used at the official dealer center Rolf and allowed to reduce the cost of managing the warehouse by 2.2 million rubles a year by maintaining the optimal level of reserves.

6 Conclusion

Studies using simulation modelling will make it possible to test how the system behaves under various conditions, such as a deficit of parts in a warehouse, or to determine the probability of producing excess stock.

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