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Spare Parts Support Optimization Algorithm based on Support Degree

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Abstract

We consider the actual situation of wartime equipment support and the different life of the old and new spare parts, in-depth analyze the impact of spare parts scheduling on the support degree, and establishe support degree model of the three levels spare parts scheduling. According to the characteristics of the model, the introduction of the classic scheduling algorithm for optimization of spare parts, can effectively improve the efficiency of support,the last example shows that the effectiveness of the method.

Keywords*: spare parts, support degree, maintenance, wartime*

1. Introduction

With the development of high-tech equipment and equipment structure complicating, more and more variety and quantity of spare parts are emerging, and a lot of battle damage equipment to restore and maintain the operational performance, which will be increasing dependence of spare parts [1].

Our spare parts scheduling are mainly two or three security, that is, the grass-roots level, the relay level and base level. Spare parts after different levels of maintenance, life is different, the life of the old and new spare parts is also different;support time of spare parts not only stored types of spare parts, and the number of the spare parts, but also closely related to the scheduling configuration of the spare parts, in certain circumstances of the spare parts storage, similar spare parts of different life configure to the same equipment, the quality and reliability of the equipment is different [2]. Therefore, in the multi-level support conditions of spare parts, support degree as the goal for the study is significant.

For the three or two levels support of spare parts, there are a lot of research, which established a number of quantitative analysis models, and determined the type and quantity of the spare parts storage in different storage levels [1-4]. Objective function to been considered mainly is to the support degree [5-6] and the availability [7-9] which is a positive correlation [4].

Wartime maintenance support are very different from the usual, there are complex and changing battlefield environment, frequent battle damage, and equipment failure rate great enhance. What we consider in wartime more is the timing, and the economy will no longer be the main factors, which determine to there be essential differences between wartime spare parts maintenance support and the usual.

Wartime battle damage equipments take one, two or three levels maintenance according to the extent of damage, location and maintenance capability [9], the service life of spare parts is different after different levels of maintenance, and the life of new spare parts and spare parts that are repaired are also different. Scientific maintenance scheduling and reasonable arrangements for the maintenance of necessary spare parts, which can greatly improve the efficiency of maintenance and equipment support degree.

2. Spare Parts Support Analysis

2.1. Multi-level spare parts support workflow

Military spare parts scheduling are mainly three security, that is, the grass-roots level, the relay level and base level. And a base level warehouse implements the supply of spare

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parts for a number of the relay level warehouse,while a relay level warehouse implements the supply for a number of the grass-roots level warehouse; the grass-roots level warehouse implements of direct support and does not exist flow of spare parts in the same level warehouse [5].

The base-level warehouse protect the equipment over a period of normal training and completion of mission as a rear warehouse,and allots a certain number of spare parts on a regular basis to relay level and grass-rootslevel warehouse as a reserve [6].

If grass-roots level is short of the spare parts in the period, and claim to the relay level;the same the relay level claim to the base level [3], and this case less, so we only consider the two-level situations [7].

All levels of maintenance functions flowchart as Figure 1.

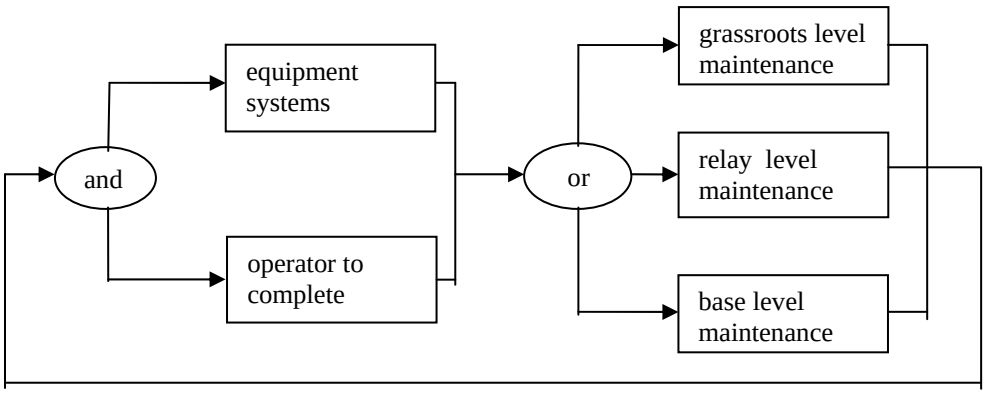

Figure 1. All Levels of Maintenance Functions Flowchart

Time diagrammed as Figure 2.

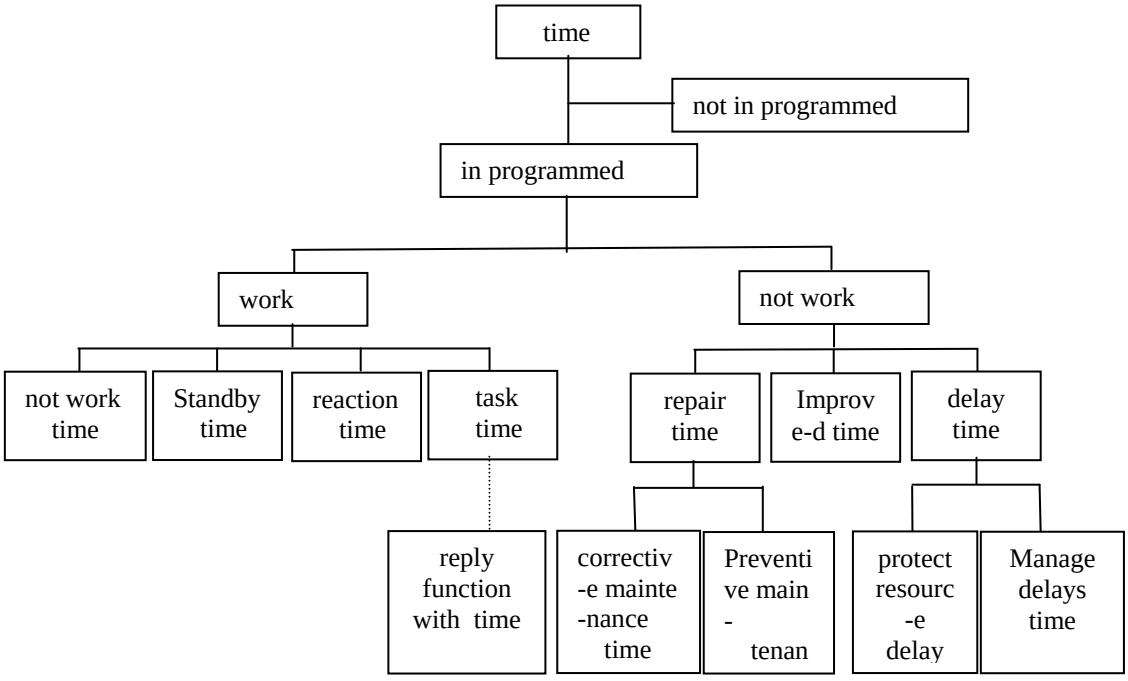

Figure 2. Time Illustrative Representation

2.2. At All Levels of Spare Parts Storage

An important factor of affecting the storage for spare parts is the price of spare parts, if taking into account of the consumption, expensive spare parts are all stored in the grass-roots

level, which is not an ideal choice, so according to ABC Management Act, this type of spare parts should be strictly controlled. Considering spare parts prices and consumption, according to the following method to determine the spare parts inventory and storage locations [8].

a) The spare parts of low consumption and high prices: such spare parts to the strict management and control as large funds, consider only stored in the relay level and base level, when the demand is generated, and then emergency transportation, to reduce overall inventory costs;

b) Low-price, low consumption of spare parts: a small amount of storage in each grass-roots level warehouse;

c) The high consumption and high prices of spare parts: these parts despite the use of funds, but its high consumption in the two storage tradeoff analysis. Relay level to the grassroots-level support to spend a long time, high cost, you can stock at the grassroots level, but to control the quantity; If support spend a short time, low cost, can be stored only in relay-level.

d) Low price and high consumption of spare parts: these spare parts should be as much as possible at the grassroots level warehouse storage [9].

2.3. The Formula of the Support Degree and Expansion

The support degree of spare parts is the ratio of equipment working hours and not working hours due to lack of spare parts in a given period of time. Average time expressed the support degree of spare parts [10].

$$A_s = \frac{\overline{U}}{\overline{U} + T_s}$$

A_s expresses the support degree of spare parts;

$\overline{U}$ expresses the average time available of the equipment;

T_s expresses the average spare parts supply delay time caused by the lack of spare parts [11] .

The support degree reflects the support of spare parts affects the extent of the equipment, spare parts support system goal is to ensure a certain support degree of spare parts. Thus can choose A_s as the objective function of the spare parts support system.

In the support degree formula, T_s expresses spare parts supply delays caused by equipment downtime. However, replacement of spare parts also causes the equipment downtime, the formula does not take into account this factor. Here we carry out more rationalization expansion of T_s ,and T_s defined as spare parts supply delays and replacement of spare parts caused by the average delay time. Therefore, due to downtime caused by the spare parts, including not only the delay time of the supply of spare parts but also the replacement of spare parts caused by the delay time, which makes the formula is more scientific and reasonable.

3. Spare Parts Scheduling Problem Analysis

3.1. Scheduling Method Introduction

Scheduling problem belongs to a class of important combinatorial optimization problem, which is the allocation of time and resources to complete some tasks, a one or a few goals to achieve optimal under certain conditions [12].

The scheduling is a very active branch in operations research, various models have been mature algorithms. These algorithms are designed not only to consider the adaptability of the model but also to consider the time complexity, has important application value.

In scheduling theory, the job is the processed object or task; Machine is the object of the provision of processing and the resources needed to complete the task [5] . Spare parts is equivalent to the job, spare parts of different life use the same equipment at different times.So the rationing problem of the spare parts is a scheduling problem.

3.2. Spare Parts Scheduling Support Problems

In two- level spare parts support system, war damage frequently and usually limited inventory, which results in the spare parts shortage is inevitable. Supported spare parts may be new spare parts, it could be relay-class supply rehabilitation, such as the old spare parts, and may also be a grass-roots level repaired spare parts. These different levels of spare parts is different lifes in the same battlefield environment, so spare parts scheduling support is to arrange the spare parts of different lifes maintenance to workers, and target to achieve optimal, thereby increasing the support level, enhancing the combat effectiveness. In this paper, the support degree as the optimization objective, using the scheduling algorithm optimization.

4. The Support Degree of Modeling

4.1. Sumptions of the Model

1) Spare parts has the different life;
2) The life of the spare parts is not necessarily the same, and spare parts are independent;
3) Moment of the last spare parts support is not less than the end of the war time.

4.2. Modeling

Set battle duration of T, the collection of weapons and equipment.

$A = \{A_1, A_2, \cdots, A_m\}$. Spare parts collection:

$$\tau = \left\{ B_{kg}{}^{x} \middle| x = a, b, g = 1, 2, \cdots, k_g, k = 1, 2, \cdots N_k \right\}$$

Where N_k is the number of spare parts types, $x = a, b$ denote respectively spare parts from the organization maintenance level, the intermediate level and depot level, $B_{kg}{}^{x}$ denotes the first k category of spare parts g from x level, and m_g^x denotes the arrival moment of the spare parts g from x level; $t_{max} = \max\{t_i\}$, $(i = 1, 2, \cdots, m)$, where t_i is the completed task time of equipment i, $p_{ikg}{}^{x}$ denote using time of the first k category spare parts g on the weapons equipment i from x level. As fighting duration of T, so $T \le t_{\max}$, the normal working time of equipment i is denote as u_i, and the time to stop working by lack of spare parts.

$$t_i \le t_{max} - u_i$$

So the total time to stop working:

$$T_s = \sum_{i=1}^{m} t_i \le m t_{max} - \sum_{i=1}^{m} u_i$$

Then:

$$A_s = \frac{\overline{U}}{\overline{U} + T_s} = \frac{\overline{U} + T_s - T_s}{\overline{U} + T_s} = 1 - \frac{T_s}{\overline{U} + T_s} = 1 - \frac{\sum_{i=1}^{m} t_i}{m \quad T}$$

$$\geq 1 - \frac{m\, t_{max} - \sum_{i=1}^{m} u_i}{m\, T}$$

The smaller $t_{\max}$, the greater A_s, that is, the optimization objective can be transformed into the maximization of completing task time.

5. Algorithm

Step 1: The spare parts has currently been served on the front of the repair shop, denoted as:

$$B_{11}^{\ a}, B_{12}^{\ a}, \cdots, B_{21}^{\ a}, B_{22}^{\ a}, \cdots, \cdots B_{N_k 1}^{\ a}, B_{N_k 2}^{\ a}, \cdots;$$

$$B_{11}^{\ b}, B_{12}^{\ b}, \cdots, B_{21}^{\ b}, B_{22}^{\ b}, \cdots, \cdots, B_{N_k 1}^{\ b}, b_{N_k 2}^{\ b}, \cdots,$$

The similar spare parts are sorted from largest to smallest according to the life, if $t < T$, then go to Step 2, otherwise go to Step 4;

Step 2: When need of spare parts, in the order of Step1 are configurated, if two or more equipment need spare parts, but a shortage of spare parts, and select a smaller number of equipment as a priority configuration object;

Step 3: Calculate spare parts to start the service moment s_{ikg}^{x}, battle damage moment t_{ikg}^{x}, and the first lack of spare parts moment T_i, go to Step 1;

Step 4: Output the maximum completion moment t_{max}, the total time of lacking in spare parts $m\, t_{max} - \sum_{i=1}^{m} u_i$

Support degree:

$$1 - \frac{m\, t_{max} - \sum_{i=1}^{m} u_i}{m\, T};$$

Step 5: Output spare par ts scheduling information: scheduling order, the number of weapons and spare parts, the source level x, the arrival time m_{kg}, the use time p_{ikg}^{x}, started time s_{ikg}^{x}, and battle damage time t_{ikg}^{x}.

6. Example

For convenience, the example only consider three types of spare parts, and set the same spare parts have the same life for the same type of equipment.

Set fault equipment collection $\{A_1, A_2, A_3, A_4\}$, arrival time, service life, the storage level of spare parts in the following table:

Table 1. The First Category of Spare Parts Arrival Time and Service Life (h)

Types	$B_{11}^{\ a}$	$B_{12}^{\ a}$	$B_{11}^{\ b}$	$B_{12}^{\ b}$
arrival time	0	0	1	1
service life	3	1	3	2

Table 2. The Second Category of Spare Parts Arrival Time and Service Life (h)

types	$B_{21}^{\ b}$	$B_{22}^{\ b}$	$B_{22}^{\ b}$
arrival time	2	2	9
service life	3	2	5

Table 3. The Third Category of Spare Parts Arrival Time and Service Life (h)

types	$B_{31}{}^{b}$	$B_{32}{}^{b}$
arrival time	1	4
service life	1	2

Set M_1, M_2 need repair at the moment one, and need the first and second categories of spare parts, the equipment M_3 need repair for the second and third categories of spare parts at the moment two; the equipment M_4 need repair for the third categories of spare parts at the moment five. Combining their arrival time and life, we can apply the algorithm to determine the scheduling program to make the support degree of the largest.

Known by the algorithm, we first sort from largest to smallest according to the life for the similar spare parts reached, the first category: $B_{11}{}^{a}$, $B_{11}{}^{b}$, $B_{12}{}^{b}$, $B_{12}{}^{a}$, as lack of the second category spare parts required, need claim to the intermediate level or depot level at this point until the moment two, we get order of $B_{21}{}^{b}$, $B_{22}{}^{b}$ and the third category: $B_{31}{}^{b}$. M_1, M_2 ask for first and second categorie of spare parts, and the first categorie $B_{11}{}^{a}, B_{11}{}^{b}$ are provided maintenance to equipment M_1, M_2 at time one, but the lack of the second category spare parts required until the moment two, we can provide $B_{21}{}^{b}, B_{22}{}^{b}$ to equipment M_1, M_2. At the moment two, M_3 fails in need of the second and third categorie of arrived spare parts $B_{31}{}^{b}$. At the moment five, M_4 fails in need of the third categorie of spare parts, and descending sort of service life: only $B_{32}{}^{b}$, so $B_{32}{}^{b}$ will be provided to M_4 for the maintenance.

7. Conclusion

Through a full analysis of the quantitative targets, we have established two- level spare parts scheduling support model, and applied the scheduling algorithm to solve the model. Less computation, can effectively improve the efficiency of wartime support.

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