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Study on the Allocation Problem of the Equipment Maintenance Support Resources

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Abstract

Aiming at the problems of lacking of system engineering method for the equipment maintenance support resource allocation problem, the problem to be solved for resource allocation is proposed from the three hierarchical perspective which is "what to allocate , how to allocate, and how much to allocate"; from the three aspects of the demand analysis, allocation method, optimizing allocation, the connotation of the problem is described, and for the each problem the essence of the problem solving method is studied systematically; the proposed method can provide science and technology support for the equipment maintenance support resources allocation scheme in the design phase.

Keywords: *maintenance support, resource allocation, demand analysis, allocation method, optimizing allocation*

1. Introduction

The maintenance support resources are the important part of the maintenance support system. Whether the demand of the maintenance support resources is scientifically predicted not only affects the life cycle cost of the equipment, but also directly affects the integrity of the equipment and the army combat effectiveness. However, in the process of the maintenance support resources allocation, some unreasonable problems often occur. On the one hand, whether in peacetime or wartime repair training, it will seriously affects the completion of the forces training and task when lacking maintenance support resources or the support is inadequate, resulting in the difficulty of forming efficient support force and combat effectiveness rapidly; on the other hand, if the maintenance support resources reserve or backlog is excessive, it will inevitably lead to a tremendous waste of resources as well as the trouble in increasing storage.

Therefore, solving the allocation problem of the equipment maintenance support resources is the material basis and significant assurance of carrying out the comprehensive support of the equipment. The ability to allocate the maintenance support resources scientifically and rationally, not only affects the life cycle cost of the equipment, but also has direct impact on the equipment readiness and combat effectiveness. That is to say, the allocation problem of maintenance support resources covers both economic issues and combat effectiveness recovery issues, while the purpose of maintenance support resources allocation is to control the maintenance cost and also meet the demand.

The paper has systematically analyzed the current domestic primary literature about the equipment maintenance support resources allocation problem, and elaborating its own viewpoints in the aspects of "what to allocate, how and how much to allocate those resources".

2. The Maintenance Support Resources Allocation Process

The maintenance support resources allocation process was shown in Figure 1.

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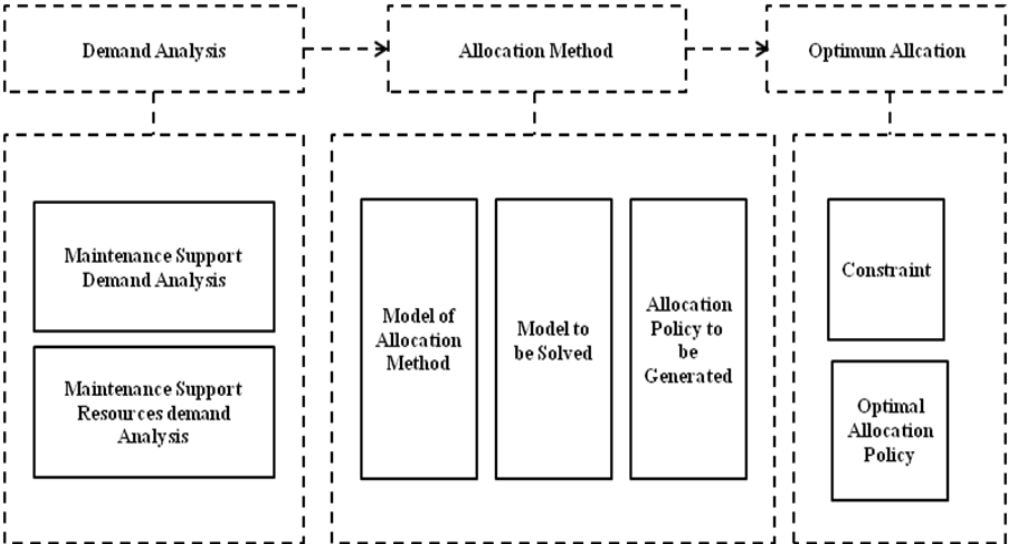

Figure 1. Maintenance Support Resources Allocation Process

The demand analysis means "what kinds of resources to allocate", through which we could gradually get the requirements of the maintenance support resources.

2.1. Maintenance Support Demand Analysis

Equipment maintenance support demand analysis simply means: what kind of maintenance support resources to be used when the equipment are in the failure? The final aim is to determine the requirements of various kinds of resources through the analysis of equipment maintenance support, for that maintenance support resources are the material basis for the implementation of maintenance support, and only if equipped with the imperative resources various can those reparation and support work be complete.

So far the maintenance support requirements analysis is fragmented, lacking standardized method. One practical and common analysis method is based on RCM (Reliability Centered Maintenance analysis), the principle of which is organizing the reliability analysis of important items of the equipment.RCM method, considering adaption and economics as its decision criteria, is based on the analysis of equipment failure modes and consequences, and determining the method of maintenance and testing, cycle, the level (who did) and activities (how to complement)by using the logical determination method .In addition, RCM method gets its maintenance program constantly improved according to the equipment’s data and experience .The basic steps of RCM method include: 1) identify important functional items; 2) determine the maintenance ways; 3) determine the contents of the maintenance work; 4) determine the level of maintenance work.

The literature on Ref 1 studies the equipment maintenance support demand analysis in the following aspects: object-oriented level analysis, tasks-oriented failure mode analysis, program-oriented maintenance strategy analysis and resources-oriented maintenance process analysis. The method has certain reference significance in providing specific process and principles for the equipment maintenance support demand analysis.

2.2. Maintenance Support Resources demand Analysis

Maintenance support resources demand analysis is to determine the type and quantities of the resources needed in the maintenance support activities, such as devices type, fuel type, human resources and so on, it is the premises of the allocation of the equipment maintenance support resources. Combined with the maintenance process and support activities information, the resources demand analysis can predict the failure and

maintenance requirements of the equipment's main features, according to the equipment structural information, maintenance tasks, reliability parameters, and failure mode.

Maintenance support resources are mainly divided into three parts, that is, material resources, human resources and information resources. When talking about the resources allocation studies, it is mainly about the allocation of material resources and human resources. Material resources mainly refer to the necessary equipment, spare parts, tools, instruments and technical materials in maintenance. Human resources include the maintenance staff dealt with technical work and the management staff from all levels engaged in maintenance management and program organization.

Thus, the main task of the resources demand analysis is to determine the type and the quantity of maintenance devices, spare parts, maintenance and human resources. The general process of the maintenance support resources demand analysis is shown in Figure 2. This process is similar with the maintenance support allocation process, but they have different emphasis.

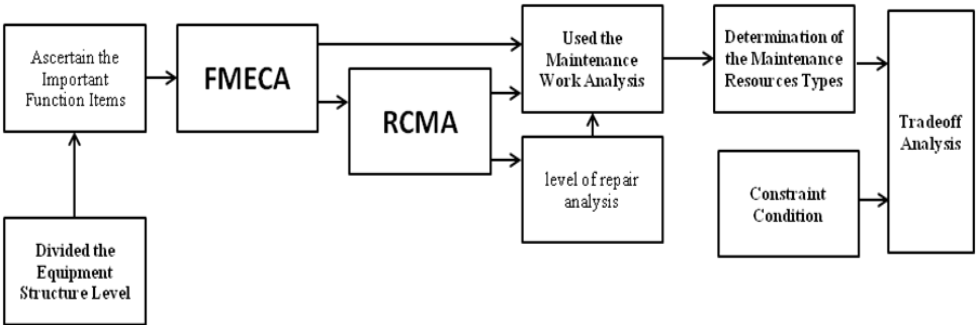

Figure 2. General Process of Maintenance Support Resources Demand Analysis

Figure 2 shows that this process is in accordance with the maintenance support demand analysis, which eventually aims to determine the requirements of the maintenance support resources.

This process can initially identify a detailed list of maintenance equipment, spare parts, personnel and other resources. In determining this list and carrying out resources plan further, a variety of methods as well constraints might be taken into consideration.

Expert Grading Method and Queuing Theory are often used in the determination of the maintenance support devices type.

Expert Grading Method is a qualitative analysis method, which is quite efficient in initially identifying the type list of the maintenance support resources. After confirming the preventive and corrective maintenance work type, maintenance intervals through support analysis, carrying out the maintenance merging work, some experts were invited to give scores to resources that might be used in maintenance. These experts all equipped with rich experiences in equipment test, production, usage and maintenance in their professional fields. Then the policymakers place the weights to different experts' evaluation scores, after calculating the final weighted scores, a preliminary list of resources will be determined.

Queuing Theory [2] is a certain quantitative calculation method, which has the constrain that the mean time to repair damage is not greater than a given value. While its target is a minimum cost of maintenance resources invested. By using the queuing theory to analyze the basic relationship among various maintenance activities, maintenance equipment resources requirements will be solved.

Fuzzy Evaluation method is often used to determine the varieties of the spare parts [3], by setting the impact aspects of spare parts, such as the importance, economics and loss,

this method could calculate the quantity on certain spare part .The calculated results, such good effect, general effect or poor effect, decides whether it could be the spare part or not.

Analogue Method, Queuing Theory and Simulation Method are often adopted in the HR demand analysis.

3. The Resource Allocation Method

Maintenance support resource allocation method goes to "how much to allocate", which is decided by the output of the demand analysis and choices for the appropriate algorithm

3.1 Determination of the Initial Number of Maintenance Equipment

3.1.1. Direct Calculation

This method directly determines device requirements based on its man-hour quota. The number of certain device(N_d) for a particular maintenance work, it is calculated as:

$$N_d = \frac{Nt_F}{T_E}$$

In this formula, N represents the total number of maintenance equipment, t_F represents the man-hour quota of a certain device required for the equipment, while T_E represents the full year valid working time for each maintenance device.

This method fails to take the mutual logical relationship among the maintenance support devices into consideration, and ignore the waiting time during the maintenance process when the devices are occupied.

3.1.2. Ratio Matching Method

This method uses the average working time of the maintenance support device to match its quantity. Its principle is: to make the equipment reach a success probability, maintenance work must be completed within a certain period of time, so if the mean working time of the maintenance device cannot meet the requirements, maintenance support devices must be increased to minimize equipment downtime. If λ represents the equipment failure rate, then the probability of reparation with the maintenance support devices used in the certain time interval [0,t] is:

$$F(t) = 1 - e^{-\lambda t}$$

Assuming that maintenance time obeys the exponentially distribution, μ to average the reparation rate, the probability of completing the maintenance work within a time interval [0,t] is as follows:

$$F(t) = 1 - e^{-\mu t}$$

Supposing that the probability for keeping the equipment intact is P_0, then

$$e^{-\lambda t} = P_0$$

then a certain time t can be calculated, and the equipment intact probability in the time slot is P_0.

and the probability of repairing the equipment in the required time is [0,t], then it goes to the quantity of support devices to reach this probability P_1:

$$e^{-\frac{\mu}{n}t} = 1 - P_1$$

Continuously using the iterative calculations, the quantity of maintenance support devices will be finally calculated. The method aims to find the number of devices with satisfying the equipment intact probability, but without considering the cost of maintenance support devices, efficiency and other factors.

3.1.3. Queuing Theory Method

Reparation and other work of the maintenance support equipment can be viewed as a random service system (queuing system), while support equipment for the service side and the maintenance projects for customers. According to analysis of the protection demand, there is a certain time limit to the downtime of the equipment, so the queuing theory can be used to determine the quantity of maintenance devices in order to meet that limited time. Ref [4-6] discusses this method in detail.

This method has been widely use. Its object function can be about the shortest time, highest maintenance efficiency and lowest cost, not only can queuing theory method calculate the quantity of devices, but also the quantity of spare parts, personnel, working hours.

3.2. Initial Quantity Determination of Spare Parts

The biggest problem to determine the initial quantity of spare parts is lacking information, so it is difficult to have a more accurate grasp on the equipment failure law. In this case, the various distribution models [7] satisfied with the spare availability have a certain precision and strong practicability in determining the initial number of spare parts. They are classified according to the types of spares' life distribution, including exponential demand calculating model, Weibull demand calculating model, and normal demand calculating model. For example: electronic spare parts belong to exponential life spares, including printed circuit board plug, electronic components, resistors, capacitors, integrated circuits, etc. Electrical and mechanical parts are usually Weibull life pieces, such as: ball bearings, relays, switches, circuit breakers, some capacitors, tubes, magnetron, potentiometers, gyros, motors, air generators, batteries, hydraulic pumps, air turbine engine, gears, valves, material fatigue spares, etc. Mechanical spare parts usually belong to normal life spares, like slip-ring, gearbox, reducer and so on.

Ref [8] choose the complex system as the research object, considering the impact of the two kinds of maintenance resources, spare parts and maintenance devices, establishing a quantitative model of the maintenance resources allocation quantity and downtime rate, and making a further optimization. The method in this literature regards the lowest maintenance resources cost as the objective function, system downtime rate as its constraints, using the marginal effect analysis method to identify the initial quantity of the spare parts and maintenance devices. The essence of the method in Ref [8] is similar with the Queuing Theory method, both are followed by the way of adding one to calculate the objective function with satisfying constraint conditions.

3.3. Quantity Determination of Maintenance Human Resource

In order to identify the demand prediction and quantity determination of maintenance human resources, we can use the maintenance devices' calculation method for references, except that its state space and solution space are discrete.

3.4. Quantity Prediction

Quantity prediction means to predict the quantity of support devices and spare parts that are going to be needed afterwards by consulting to the service condition of support devices and spare parts during a specific period when the equipment is under service and maintenance support.

According to the features of equipment support resources during support activities and in light of quantity prediction of equipment support resources, Ref [9] divides resources including spare parts, support devices and tools, manpower, support decides ,technical materials, packaging containers, oil, ammunition into two categories, namely consumption resources and occupation resources.

The feature of consumption resource is that it needs to be continuously replenished, and the quantity needed shows a linear increment along with the implement of corresponding activities. The feature of occupation resource is that its required quantity is related to the time during which it is occupied in corresponding activities. Once the design features of the equipment are determined, the quantity of the occupation resource depends upon the frequency of support activities.

In the Ref [9], the calculation model does not take into account of the impacts of environmental and manpower factors on quantity prediction.

The Ref [10] divides support resources into four categories: specific consumption resource, general consumption resource, specific occupation resource and general occupation resource. Models to predict required quantities of these four kinds of resources are presented. Impacts of environmental and manpower factors are considered in the four models.

Calculations showed in the Ref [9] and Ref [10] can be used to predict the quantities of maintenance support devices, spare parts, personnel, oil, *etc*. Under varying conditions, the differences lay only in the known parameters and complexity in doing calculation.

4. Optimum of the Resources Allocation

The output of maintenance support resources allocation method is "how much to allocate". The direct result of algorithm can meet the basic requirements of maintenance support, but may be "unreasonable", such as resources squandered or free. Therefore, it demand to combine repair mission requirements. The output which makes the maintenance support resources allocation methods and maintenance demand balanced is the number that actual maintenance support resources need to be equipped, which means "reasonable allocation "realizes "match".

The optimal allocation of equipment maintenance support resources can effectively avoid the waste of individual maintenance resources, short supply, maximize utilization of maintenance resources and ensure the need of weapons and equipment maintenance, reduce the equipment cycle cost.

Three factors need to be considered in realizing the target of optimal allocation of maintenance support resources: cost, time and efficiency. That is to say, the basic principle of optimization is, saving the cost, shortening the construction period, reaching regulates efficiency. Thus, the problems of optimal allocation is a multi-objective optimization problem, the solutions are: Genetic Algorithm [11-12], Stimulated Annealing Algorithm [13], Ant Colony Optimization, Particle Swarm Optimization [14], *etc*. Various optimization methods have various advantages and disadvantages, it's the specific situation decides which method to use or improve [15].

5. Conclusion

The allocation of maintenance support resources is a complex issue with intricate realization process, it requires a comprehensive application of various methods to optimize all the aspects of resources allocation, so as to improve the intelligent allocation of maintenance support resources as a whole .Consequently, in the study of maintenance support resources allocation ,how to select the appropriate method in each allocation step, making best use of its advantages and avoiding its disadvantages, has become the key issue.

References

[1] C. He, F. Sun and J. Jin, "Research on Equipment Maintenance Support Requirement Analysis", Control Engineering of China, vol. 19, no. 5, **(2012)**.
[2] B. Zhang, Y. Yu and C. Qu, "Method to Analyze Maintenance Resources Requirement Based on Queueing Theory", Journal of Ordnance Engineering College, vol. 23, no. 4, **(2011)**.

[3] Y. Cheng, Z. Yang and J. Che, "The Demand Analysis of Spare Parts Varieties Determination based on the Fuzzy Comprehensive Evaluation", Journal of Sichuan Ordnance, vol. 29, no. 2, **(2008)**.
[4] J. Wenhao, M. A. Naicang and B. I. Yuquan, "The Research on Aviation Support Allocation of Resources based on Queuing Theory", Value Engineering, vol. 15, no. 5, **(2010)**.
[5] D. Mao, G. Lin and S. He, "Warship Maintenance Support Model Based on Queuing Theory", Ordance Industry Automation, vol. 31, no. 6, **(2012)**.
[6] B. Zhang, Y. Xu and Y. Dong, "Method of maintenance Support Unit Configuration Optimization based on Queuing Theory", International Conference on Services Science, Management and Engineering, **(2010)** October 15-19, China Beijing.
[7] "GJB4355-02.Spares provision requirements", **(2002)**.
[8] J. Zhiyu, W. Lichao and W. Naichao, "Maintenance Recource Configuration Model for Complex System based on Downtime", Computer integrated manufacturing Systems, vol. 16, no. 10, **(2010)**.
[9] L. Guo, R. Kang and J. Wen, "Quantitative Forecast of Support Activity Centered Equipment Support Resources", Acta Aeronautica Et Astronautica Sinca, vol. 30, no. 5, **(2009)**.
[10] Y. Wang, J. Xisheng and L. Cai, "Modeling on Maintenance Resources Requirement Prediction for System of Multi-Kinds Equipments", Microcomputer Information, vol. 28, no. 2, **(2012)**.
[11] B. Sun, X. Sun and Z. Cheng, "Study on Model for Equipment Maintaince Resource Optimization in Wartime", Fire Control and Command Control, vol. 36, no. 6, **(2013)**.
[12] X. Zhang, J. Zhao and Y. Zhang, "Optimized Dispatching of Warship Maintenance Resources Based on Ant Colony Algorithm", Ordnance Industry Automation, vol. 30, no. 11, **(2011)**.
[13] A. I. Baoli and W. U. Chang, "Genetic and Simulated Annealing Algorithm and its Application to Equipment Maintenace Resource Optimization", Fire Control and Command Control, vol. 10, no. 1, **(2010)**.
[14] T. Niu, J. Wang and Y. Du, "Researches of maintenance and support resources scheduling in battlefield based on μPSO algorithm", Computer Engineering and Applications, vol. 47, no. 9, **(2011)**, pp. 210-213.
[15] J. Jing, "Optimization Techniques for Equipment Maintenance Support Resources in China: A Literature Review", Chinese Journal of Ship Research, vol. 8, no. 4, **(2013)**.

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