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Effectiveness Analysis of Missile System Support Ability

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Abstract. An efficacy evaluation model of a certain missile technical support system is established by adopting ADC method. Both important influencing factors and evaluation index of system effectiveness are determined via analyzing the missile technical support process. Simulation results show that the proposed model can assess the objective reflection of missile's equipment support system, as well as providing the active guidance.

Introduction

A large number of powerful complex new missiles have been armed with the development of technology and troops' demand. Missile must possess advanced tactical missile technical, good performance and perfect comprehensive support capability in order to achieve high operational effectiveness. Missile's technology support system is an important factor to maintain, restore and improve the battle effectiveness. Because it can not only affects the operational readiness of a whole weapon system but also its operational effectiveness.

A type missile is a air-launched cruise missiles self-developed in China. It is mainly used outside the enemy ground air defense field of fire to attack the high-value ground stationary target in enemy territory. The technical support system of this type missile is typical because of more support links and complex process. The effectiveness of technical support system should be evaluated in view of the complexity of missile weapon equipment and the diversity of its tactical and technical index. A reasonable scheme can be only concluded on the basis of the whole technical support process and all kinds of influencing factors must be considered. The research can provide a reference for the same kind of guided missile support work and theoretical basis for operational decision.

Definition Of Equipment Technical Support System Effectiveness

Efficiency refers to the ability of the system to satisfy the given quantitative characteristics and service requirements which under the prescribed conditions. Efficiency must have a boarding "subject" and depend on the role of active process .It is neither exist dependently nor in a vacuum. Complex technical support system has a series of technical indicators of various characteristics frequently. These parameters are involved in all aspects of the equipment technical support system. In terms of equipment technical support effectiveness, the "subject" is equipment technical support system; the "active process" means the process of technical support activities.

The efficiency of equipment technical support system refers to the effective level of the technical support system which is used to perform the specific tasks to achieve the desired objectives under certain conditions. The efficiency of equipment technical support system is not only related to the types, quantity and quality of the equipment, but also the support resources [1]. The purpose of the effectiveness evaluation is to identify the level of technical support and the progress of construction and find the shortcoming of existing support system [2]. The balance between support requirements and the capacity supply of support institution of the troop should be studied via the effectiveness evaluation. The effectiveness evaluation can provide the basis for planning system construction and the schedule of support institution.

There are many factors influence the effectiveness analysis of missile's equipment technical

support system, including basic factor, restrictive factor, self-factor of troop, external factor and environment. According to the definition of equipment technical efficiency, the influencing factors are mainly divided into two categories: internal factor of inherent ability and external factor.

The missile's equipment technical efficiency mostly lies on the design features related to missile's support equipment, such as reliability, maintainability, testability, security, "man-machine-environment" characteristic and supportability as well as the adequate degree of support resources. The technical efficiency of missile's equipment is a dynamic process. It describes an influencing degree, which the equipment technical support system converts potential ability into actual effect. Therefore, the specific tasks of various stages must be analyzed, and the mission requirements can be concluded by mission profiles. Following, the important influencing factors should be selected.

Missile Technical Support System Effectiveness Evaluation Model

Effectiveness evaluation method mainly can be divided into three categories: performance parameter method, analytical method and counter method. Performance parameter method is used to describe the system's operational effectiveness based on some typical performance index, which mainly include performance comparison method, expert grading method and performance index method. Analytical method is used to conclude the system's operational effectiveness on the basis of mathematical methods such as queuing theory, game theory, military operations research, Lanchester equation, etc. Analytical methods mainly include analytic hierarchy process (AHP), SEA method, fuzzy comprehensive evaluation method, grey evaluation method, WSEIAC model method, etc. Counter method consists of actual combat maneuver and computer simulation, which is used to verify the operational effectiveness of weapon system via actual or simulated fighting against. Currently, ADC method is widely used and deeply affects the effectiveness evaluation [3].

ADC method is an efficiency evaluation method based on the weapon system effectiveness analysis model of WSEIAC (The Weapon System Effectiveness Industry Advisory Committee)[4]. The index system of ADC method consists of system availability, system dependability, system task capability. System efficiency is a function of system availability, system dependability and system task capability [5]. The mathematical expression of system efficiency can be calculated as:

$$E = A \cdot D \cdot C \tag{1}$$

E-System Effectiveness;

A-System Availability;

D-System Dependability;

C-System Task Capability.

According to systems engineering's research method [6][7], the effectiveness evaluation of a type technical support system should abide by some steps.

Analysis of evaluation object

On the basis of systems engineering and integrated support engineering's theory, the evaluation objects of a type missile's technical support system should be analyzed as follow: system's composition and function, various influencing factors of system and the premise, conditions, regulation and goal of evaluation.

2. Establish evaluation index

One of the main content of effectiveness evaluation is to set up the evaluation index system, which is the important foundation and basis of technical support system evaluation. A scientific justice evaluation index system can be established during deeply analyze on research object. This index system should reflect the performance characteristics of the equipment support system. Furthermore, it is a general abstract result on the basis of simplification. Currently, the main existing problems of the efficiency evaluation index system can be recognized as following:

More qualitative indicators were generated by subjective factors, high correlativity and more weighting system;

More static indexes which reflect technical support system's amount and kinds, while lacking of consideration on the inherent quality and dynamic performance of equipment.

Therefore, the principle for establish the evaluation index system includes: 1. scientific principle; 2. system principle; 3. perfect principle; 4. feasibility principle.

Effectiveness Evaluation Index System

As a comprehensive index to measure system's performance, system effectiveness should include three aspects: (1) Availability or combat readiness; (2) Task reliability; (3) Ability or performance [8].

Availability analysis. The availability of a certain type missile's technical support system indicates the extent of a system, which is required to perform a task at any time, is in a trouble-free state. The measure index is availability. System availability lies on system reliability and system maintainability for a repairable system before performing a task, while depending on its inherent reliability.

A technical support system of a certain type missile is consists of many different kinds support equipment which is made of many parts. Similar to various type equipment, different parts of single equipment form a series system, and the whole technical support system is a repairable system before performing a task. Therefore, the availability of a series system which is consists of n type different parts can be calculated by applying Markov process. Calculate steps are following:

Assume, a technical support system is composed of n types different equipment, and the failure rate and repair rate of n types different equipment equal to λ_i and μ_i ,($i = 1, 2, ...n$) respectively.

System's availability can be written as follow formula via calculation.

$$A = \frac{1}{1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}} \tag{2}$$

Creditability analysis. System's creditability indicates the extent of a system is in normal working condition during performing a task. The measure index of creditability is reliability, which means the probability of a working system is in normal state. System's creditability lies on system's reliability and maintainability for a repairable system, while lies on mission reliability. The creditability of a missile system lies on the reliability and maintainability of each equipment because the missile's technical support system is a repairable system.

Capability Analysis. Capability analysis is one of the most important and complex parts of a system's effectiveness evaluation. System's capability indicates the extent of a system which completes a given task in the final stages. The measure index of capability is the probability of a system which completes a given task. For missile's technical support system, the aim of a task is supply missiles which can meet operational requirements in the available time.

Effectiveness Evaluation Analysis

Four key links were regarded as analytic objects combined with missile's technical support procedure. They are test equipment, hoisting equipment, and explosive test equipment and refuel equipment.

Assume:

To test equipment: $MTBF_1 = 1 \times 10^6 \text{h}$, $MTTR_1 = 10\text{h}$

To hoisting equipment: $MTBF_2 = 3500\text{h}$, $MTTR_2 = 6\text{h}$

To explosive test equipment: $MTBF_3 = 5000\text{h}$, $MTTR_3 = 8\text{h}$

To refuel equipment: $MTBF_4 = 9000\text{h}$, $MTTR_4 = 7\text{h}$

The probability of a system which completes a given task equals 1 if all equipment were in normal working condition, while the probability equal to 0.85.The technical support system of missile is a repairable system, and the life and repair time of each subsystem's equipment were considered as obey index distribution. On the basis of actual situation, two kinds of equipment can't

happen to fault at the same time and mission time was regarded as 12h.

Availability analysis. The technical support system of a certain type missile is consisted of four subsystems in series; the state of system can be described as following:

State 0: All equipment is normal;

State 1: test equipment is fault, others are normal, system is fault;

State 2: hoisting equipment is fault, others are normal, system is fault;

State 3: explosive test equipment is fault, others are normal, system is fault;

State 4: refuel equipment is fault, others are normal, system is fault;

The state of the system can be divided into two categories: normal and fault.

The available vector of the system can be represented as:

$$A^T = \left(a_1, a_2\right) \tag{3}$$

Where a_1 is availability, a_2 is unavailability, and $a_1 + a_2 = 1$.

According to availability theory, the calculation formula of single equipment's inherent availability can be represented as:

$$A = \frac{MTBF}{MTBF + MTTR} \tag{4}$$

So the availability of a series system can be represented as:

$$A_s = \prod_{i=1}^{n} A_{i,} \left(i = 1, 2, \cdots, n\right) \tag{5}$$

Creditability analysis. Due to the missile system is a repairable system; the state of the missile system can be regarded as two states: normal and fault. The creditability matrix of a missile system can be represented as:

$$D = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \tag{6}$$

$$d_{11} = \frac{\mu_s}{\lambda_s + \mu_s} + \frac{\lambda_s}{\lambda_s + \mu_s} e^{-\left[-\left(\lambda_s + \mu_s\right)^T\right]} \tag{7}$$

$$d_{12} = 1 - d_{11} = \frac{\lambda_s}{\lambda_s + \mu_s} \left\{1 - e^{-\left[-\left(\lambda_s + \mu_s\right)^T\right]}\right\} \tag{8}$$

$$d_{21} = \frac{\mu_s}{\lambda_s + \mu_s} \left\{1 - e^{-\left[-\left(\lambda_s + \mu_s\right)^T\right]}\right\} \tag{9}$$

$$d_{22} = 1 - d_{21} = \frac{\lambda_s}{\lambda_s + \mu_s} + \frac{\mu_s}{\lambda_s + \mu_s} \left\{1 - e^{-\left[-\left(\lambda_s + \mu_s\right)^T\right]}\right\} \tag{10}$$

Where, T is the working hours of a system.

$$\lambda_s = \sum_{i=1}^{n} \lambda_i \tag{11}$$

$$\mu_s = \frac{1}{MTTR_S} \tag{12}$$

$$MTTR_S = \sum_{i=1}^{n} MTTR_i \ / \ n \tag{13}$$

So, $E = 0.9974$.

Conclusion

Result shows that, the support effectiveness of a certain type missile can reflect the reality and in good state under this condition.

Reference

[1] Yang dongbo. Effectiveness Evaluation of Surface-to-Air Missile System [D]. Nanjing University of Science & Technology, 2013.

[2] Li jianguo. Efficacy Evaluation of Missile Weapon System on Support Ability [J]. 2010(1).

[3] Liu Huayun, Zhang Xianchun. Effectiveness Evaluation Method Of Missile Weapon System Based on ADC [J].2015(8).

[4] Peng Cishu, Guo Lei, Wang Zhiqian. Efficiency Evaluation Research on Air-defense Missile Systems [J].2015(8).

[5] Wang Jun, Zhao Jie, Shao Lei, LI Jin. System Effectiveness Evaluation Model of Ground to Air Missile Based on ADC Method [J].2015(12).

[6] Wang Xuan, Tao Yu, Fan Danying. Research on Effect Valuation to the Complicated Weapon System Based on ADC [J].2016(2).

[7] BaoMing, Dai Yuewei, Kong Jianshou, Zou Yu. ADC effectiveness evaluation model with preventive maintenance [J].2010(7).

[8] Hou Lifeng ,Xiong Zhe , Sheng Jing-jun. Model of Efficiency Evaluation on Flight Support System based on ADC Method[J].2010(10).