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Cost-effectiveness Analysis of Military and Civilian Integration Equipment Maintenance Support Task Distinction

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Abstract. in view of the problem of the task differentiation of the integrated maintenance and maintenance units of military and civilian equipment, this paper, based on the analysis of the influencing factors of the task differentiation, establishes the cost and effectiveness model of the contractor and the force of the troops, and then establishes the cost efficiency ratio model under the different maintenance strategies, and finally compares the cost efficiency ratio of the unit time by comparing the cost efficiency ratio. Function to distinguish between civil and military equipment maintenance support tasks. The results show that the method is scientific and effective, and it can provide certain reference for the task division of equipment maintenance support units.

Keywords: cost effectiveness analysis; civil military integration; equipment maintenance support; task distinction.

1. Introduction

With the injection of high and new technology, the complexity of equipment is gradually increasing, and the difficulty of maintenance is becoming more and more difficult. The maintenance support force only by the army itself can not meet the increasingly heavy task. In this case, the maintenance support task with the help of local maintenance support force has become an inevitable choice to solve the contradiction and problems of maintenance support for complex equipment. When the equipment is in the initial warranty period, the contractor will be more familiar with the performance of the equipment, so the task will be handed over to the contractor. In the extended warranty period, the force has not formed a comprehensive maintenance support capacity and requires the contractor to continue to provide part of the maintenance support service. At this time, the contractor and the force maintenance support force each undertake a part of the maintenance task [1]. But how to distinguish and optimize maintenance tasks has become an urgent problem. For the maintenance support of the military and civilian integration equipment, it is necessary to solve the problem of the distinction between the military and the civilian, which is to distinguish which equipment, which maintenance tasks are undertaken by the military and which can be paid by the local, in order to better improve the quality and efficiency of the equipment support[2].

In the current research on maintenance support task differentiation, many scholars have been exploring continuously. In view of the difference between the core equipment support and the non core equipment support, Huang Shaoluo[3] has analyzed the connotation of the core coefficient and distinguishes the core and non core tasks of the equipment; Cao Huizhi et al [4], combined with the specific conditions of the vehicle equipment, and according to the different requirements for the protection of the contract, makes a reasonable division of the tasks of the contract merchants to protect the obstacles; Yao Junjin[5] faces the problems existing in the current equipment maintenance guarantee, the model of task differentiation is clarified with the help of QFD method, and a QFD model is established to provide a solution for the division of maintenance and support tasks for high and new equipment. Cai Liying et[6] al have made a thorough analysis of the distribution process and judgment criteria of military and ground tasks, and made clear the basis for the assignment of tasks. This principle and the general steps have laid the foundation for the distribution of military and ground tasks of the model equipment. According to the situation of different maintenance levels, Chen Bing[7] analyzes the influence of the level of equipment integrity and the growth of talents, and puts forward the method of the maintenance assignment based on the requirements of the equipment integrity and the law of talent growth. However, due to the complexity and uncertainty of the task differentiation problem of the military and civilian integration maintenance support units, there are many factors involved, but the existing research fails to make a full quantitative analysis of the default risk of the maintenance strategy and the contractor, and lacks the quantitative analysis of the task differentiation from the Perspective of cost and efficiency. Analysis of the study.

In this paper, the cost efficiency ratio method is used to distinguish the maintenance support tasks of the military and civilian fusion equipment, which can meet the minimum level of the scheduled tasks and targets, and make the system resource consumption reach the minimum, thus achieving the optimal allocation between the overall efficiency and the cost of consumption. By combining different maintenance strategies, warranty period and failure rate, the task differentiation and optimization model of integrated maintenance support unit for military and civilian military and civilian is constructed to provide reference for the rational use of maintenance force of equipment maintenance support.

2. Analysis of Cost and Effectiveness of Military and Civilian Integration Equipment Maintenance

Based on the cost efficiency ratio, the division of the integrated maintenance support unit of military and civilian equipment is mainly based on the factors such as the cost efficiency ratio of the equipment, the maintenance strategy, the default risk and the delay risk. By calculating the cost efficiency ratio of the equipment after maintenance of different maintenance methods, the military and civilian integration maintenance is formed according to the division of military and land tasks. The cost efficiency ratio model establishes the task optimization model of the general equipment military and civilian integration maintenance support, and finally forms the task optimization scheme for the maintenance support of the military and civilian integration equipment through the optimization model.

When undertaking task differentiation, the following major issues need to be considered:

(1) maintenance strategy. Maintenance strategy includes preventive maintenance and repair maintenance. In consideration of preventive maintenance time, it should be taken into consideration that the contractor, if there is a delay in preventive maintenance caused by breach of contract, should also take into account the preventive maintenance delay caused by a contract dealer if a breach occurs, and the restorative maintenance is in the state of "repair as new" and "repair as old" after maintenance. The incomplete maintenance strategy should also consider the delay time caused by the Contractor's default[8].

(2) availability. Availability refers to the probability that the equipment is in a working or usable state when it is required and started to perform a task at any random time. It is one of the most concerned parameters in the equipment use department. In the guarantee of the Contractor's participation, the availability is also related to the default risk and delay risk of the contractor. The outage time in the use of availability model includes the average maintenance time (MTBM) and the average maintenance time (MDT). Under the military and civilian integration support mode, the difference of MDT under different guarantee modes is very big, so the emphasis is given.

(3) shutdown time after equipment failure. Downtime involves many factors, including maintenance time, improvement time and delay time. In the process of equipment use and support, downtime usually does not include improvement factors. Generally, only the maintenance operation and supply delay factors are considered. The delay time of the maintenance operation should be considered for all preventive maintenance and repair time; the delay time of the supply is the delay time of the logistics, and the influence of spare parts supply, personnel delay, facility delay, equipment delay and management delay should be taken into account[9].

Through the analysis of the maintenance strategy, default risk and delay risk, this paper first establishes the effectiveness model of the contractor and the force maintenance force under the preventive maintenance and repair strategy, and then establishes the cost model of the Contractor under the condition of default and delay, combined with the cost model of the force building force, and the comprehensive establishment of the cost. The efficiency ratio model is used to compare the cost effectiveness ratio between the two sides and determine the task allocation.

3. The Establishment of the Cost Efficiency Ratio Model

3.1 Basic Assumptions

According to the degree of recovery after equipment maintenance, it can be divided into five types: complete maintenance, incomplete maintenance, minimum maintenance, deterioration maintenance and worst maintenance. The traditional complete maintenance method, the cost is too high, maintenance support units are often difficult to bear, under the operation of the market economy, the people Fang Weixiu guarantee units tend to pay more attention to enterprise profits, so the complete maintenance method is not suitable. Based on the minimum maintenance and incomplete maintenance optimization model, the basic assumptions are as follows:

(1) at present, in view of the difficulty and low quantity of high precision equipment, the army set up the level of repair, not only the time is long, but also the cost is high. Therefore, the US Army adopts the performance based guarantee mode, and has achieved good military and economic benefits. For the newly installed general equipment, both military and local governments have formed maintenance support capabilities, and the distinction between the two maintenance support tasks is particularly important.

(2) it is assumed that the replaceable unit will perform incomplete repair during the contract period. After the incomplete repair of the product, the failure rate is between "repair" and "repair like the old", and the failure rate of the product is not changed after the preventive maintenance.

(3) in the process of using the product, it is only in two states, normal state and fault state.

(4) the product has aging characteristics, and the failure rate increases with age.

(5) the preventive maintenance cost per input is a constant and does not vary with the number and age of maintenance.

(6) the occurrence time of potential faults is U, and its distribution function is $G(u)$.

(7) the delay time is H, and its distribution function is $F(h)$;

(8) state detection at time t_i, $t_i = T_1 + (i-1)T, (i = 1, 2, \dots)$, where T_1 is the first detection interval, and T is the repeated detection interval.

(9) replace the product if there is a potential fault detected in the test, otherwise the product will work until there is a functional failure or wait until the next inspection.

(10) when detection is perfect, as long as there is a fault, it can be detected and there will be no false positives.

(11) $\lambda_i(\mathrm{t})$: probability of failure at any time before t.

3.2 Failure Rate Model

The probability of failure at any time under the state detection strategy can be expressed as: when the period of unlimited use and potential failures are unmeasurable,

$$\lambda_i(\mathrm{t}) = 1 - \bar{\lambda}_i(\mathrm{t})$$

$$\bar{\lambda}_i(\mathrm{t}) = \begin{cases} 1 - \int_0^t g(u)du + \int_0^t g(u)[1 - F(t-u)]du & t \le t_1 \\ 1 - \int_0^t g(u)du + \int_0^t g(u)[1 - F(t-u)]du + \sum_{j=1}^{i} \int_{t_{j-1}}^{t_j} g(u)[1 - F(t_j - u)]du\, \bar{\lambda}_i(\mathrm{t} - t_j) & t > t_1 \end{cases}$$

According to the statistical analysis, the fault rule of the component is roughly subject to the Weibull distribution of the initial time parameter $\alpha_u = 1.5$, $\beta_u = 100$,the Weibull distribution of the delay time parameter $\alpha_h = 1.5$, $\beta_h = 50$.

3.3 Availability Model

The availability of equipment indicates the probability that the system can maintain normal working conditions at any time under the prescribed conditions.

$$A_1 = \frac{W - D(T)}{W} \tag{1}$$

W indicates that the term of use is the contract guarantee period; T is the preventive maintenance interval; and $D(T)$ is the expected downtime.

The maintenance delay time and logistical delay of the army maintenance force are not existed because of the absence of breach of contract. Therefore, the stopping time is expected to be the preventive maintenance time, the replacement of the failure time during the maintenance interval and the repair time, and the expected stopping time of the contractor is the preventive maintenance time and the replacement of the maintenance interval. The sum of downtime, repair time, contract maintenance delay and logistical supply delay time.

The expected downtime for contractors during preventive maintenance intervals is:

$$\sum_{i=1}^{n} ET_{fia}(T) = \sum_{i=1}^{n} \int_{(i-1)T}^{iT} \lambda_i(\mathrm{t})\,\mathrm{dt} \times T_{fa} \tag{2}$$

The expected downtime for maintenance support forces during preventive maintenance intervals is:

$$\sum_{i=1}^{n} ET_{fib}(T) = \sum_{i=1}^{n} \int_{(i-1)T}^{iT} \lambda_i(\mathrm{t})\,\mathrm{dt} \times T_{fb} \tag{3}$$

The repair time of the Contractor shall be as follows:

$$ET_{fa}(W - nT) = \int_{nT}^{W} \lambda_{(\mathrm{n}+1)}(\mathrm{t})\,\mathrm{dt} \times T_{fa} \tag{4}$$

The repair time of the force maintenance force is as follows:

$$ET_{fb}(W - nT) = \int_{nT}^{W} \lambda_{(\mathrm{n}+1)}(\mathrm{t})\,\mathrm{dt} \times T_{fb} \tag{5}$$

W means the duration of contract warranty; T is a preventive maintenance interval, T_{wa} is the delay time caused by default for the contractor to repair the contract, P_{wa} is the risk probability of the contract dealer's repair default, T_{ya} is the delay time of the Contractor's logistics supply, the P_{ya} is the risk probability of the delay of the service supply delay after the contractor, T_{pa} is the probability The time of preventive maintenance by the contractor, T_{pb} is the preventive maintenance time for the force maintenance force, T_{fia} is the i of the contractor to replace the failure expected time in the interval period of the maintenance interval, T_{fib} is the i of the army maintenance force in the replacement interval period, the T_{fa} is the repair time for the contractor, and the T_{fb} is the force maintenance force. The amount of repair maintenance time, $\lambda_i(t)$ for the first i update cycle product failure rate, n is the number of periodic repairs.

To sum up, the expected stoppage time of the contractor is the preventive maintenance time, the replacement of the failure time during the maintenance interval, the repair time, the delay time of the maintenance and the delay time of the logistics supply, and the formula is as follows:

$$D_a(T,W) = nT_{pa} + \sum_{i=1}^{n} ET_{fia}(T) + ET_{fa}(W - nT) + T_{wa} \cdot P_{wa} + T_{ya} \cdot P_{ya} \quad (6)$$

The maintenance delay time and logistical delay of the army maintenance force are not existed because of the absence of breach of contract. Therefore, the stopping time is expected to be the preventive maintenance time, the replacement of the failure time during the maintenance interval, and the sum of the repair time. The formula is as follows:

$$D_b(T,W) = nT_{pb} + \sum_{i=1}^{n} ET_{fib}(T) + ET_{fb}(W - nT) \quad (7)$$

The formula (6) substituting (1) can get the availability of the equipment after the Contractor's maintenance strength is maintained (expressed in X, hereinafter referred to as X and X).

$$A_a(T,W) = 1 - \left[nT_{pa} + \sum_{i=1}^{n} ET_{fia}(T) + ET_{fa}(W - nT) + T_{wa} \cdot P_{wa} + T_{ya} \cdot P_{ya} \right] / W \quad (8)$$

The formula (7) is substituted for (1), and the equipment availability after maintenance is guaranteed.

$$A_b(T,W) = 1 - \left[nT_{pb} + \sum_{i=1}^{n} ET_{fib}(T) + ET_{fb}(W - nT) \right] / W \quad (9)$$

3.4 Cost Model

Although the maintenance support costs mainly include facilities, equipment, maintenance manpower and maintenance activities, the units do not model the facilities, equipment, and maintenance manpower in detail to describe the convenience, but share these costs into the cost of each specific maintenance activity, and the cost of maintenance activities will be from Remedial maintenance costs and preventive maintenance costs are taken into consideration. A preventive maintenance strategy based on timed replacement model is adopted for a certain type of equipment. It is assumed that the preventive maintenance of the parts per time is T , the Contractor's preventive maintenance cost is C_{pa} , the Contractor's repair cost is C_{fa} , and the C_{wa} is the contract dealer's repair delay cost caused by the breach of contract, P_{wa} is the risk probability of the Contractor's repair default, C_{ya} is the delay of the contract merchant's logistics supply. Cost, P_{ya} is the risk probability for the Contractor's logistical supply delay. T_{wa} is the delay time caused by breach of contract for the contractor to repair the contract P_{wa} is the risk probability of the Contractor's repair default, T_{ya} is the delay time of the Contractor's logistics supply, and P_{ya} is the risk probability of the delay in the logistics supply of the contractor.

In the case of the contractor, the cost of preventive maintenance is:

$$\sum_{i=1}^{n} EC_{fia}(T) = \sum_{j=1}^{n} C_{pa} \left\{ 1 - \frac{[jT + (j-1)T_{pa}]^2}{W^2} \right\} \quad (10)$$

The preventive maintenance cost of troops maintenance support force is:

$$\sum_{j=1}^{n} EC_{fib}(T) = \sum_{j=1}^{n} C_{pb} \left\{ 1 - \frac{[jT + (j-1)T_{pb}]^2}{W^2} \right\} \quad (11)$$

The repair cost of the contractor is:

$$EC_{fa}(W-nT)=\sum_{i=1}^{n}\int_{(i-1)(T+T_{pa})}^{iT+(i-1)T_{pa}}\lambda_i(t)dtC_{fa}+\int_{n(T+T_{pa})}^{W}\lambda_{(n+1)}(t)dtC_{fa} \tag{12}$$

The repair cost of the force maintenance force is:

$$EC_{fb}(W-nT)=\sum_{i=1}^{n}\int_{(i-1)(T+T_{pb})}^{iT+(i-1)T_{pb}}\lambda_i(t)dtC_{fb}+\int_{n(T+T_{pb})}^{W}\lambda_{(n+1)}(t)dtC_{fb} \tag{13}$$

To sum up, the maintenance cost of the contractor C_a^* is the preventive maintenance cost, the replacement of the breakdown cost in the period of the maintenance interval, the repair cost, the maintenance delay cost caused by the contract dealer default and the delay cost of the logistics supply. The formula is as follows:

$$C_a^*=\sum_{j=1}^{n}C_{pa}\left\{1-\frac{[jT+(j-1)T_{pa}]^2}{W^2}\right\}+\sum_{i=1}^{n}\int_{(i-1)(T+T_{pa})}^{iT+(i-1)T_{pa}}\lambda_i(t)dtC_{fa}+\int_{n(T+T_{pa})}^{W}\lambda_{(n+1)}(t)dtC_{fa}+C_{wa}\cdot P_{wa}+C_{ya}\cdot P_{ya} \tag{14}$$

The maintenance delay and logistical delay caused by no breach of contract for the force maintenance force C_b^*, the maintenance cost is the preventive maintenance cost, the replacement of the breakdown cost and the repair maintenance cost in the interval period, and the formula is as follows:

$$C_b^*=\sum_{j=1}^{n}C_{pb}\left\{1-\frac{[jT+(j-1)T_{pb}]^2}{W^2}\right\}+\sum_{i=1}^{n}\int_{(i-1)(T+T_{pb})}^{iT+(i-1)T_{pb}}\lambda_i(t)dtC_{fb}+\int_{n(T+T_{pb})}^{W}\lambda_{(n+1)}(t)dtC_{fb} \tag{15}$$

3.5 Cost Efficiency Ratio Function Model

From the cost model and the effectiveness model, there is a balance between the two. It is necessary to find a balance point in which the best benefit is obtained, and the cost efficiency ratio can be obtained by calculation. The ratio of cost to efficiency is the ratio of cost to efficiency.

$$K(T,W)=\frac{C(T,W)}{A(T,W)} \tag{16}$$

Among them, K is cost effective ratio, C is cost, A is efficiency (availability).

3.6 Optimization Model

The operational environment of weapon and equipment is complex. In order to meet the daily training and operational requirements of troops, the availability of high standard equipment must be guaranteed. The availability of equipment or sub systems is often proportional to the cost of maintenance support, which means that the availability of equipment is constrained by the cost of maintenance support in the case of maintenance support.

In the process of optimization, the total cost and availability of the contract should be considered at the same time. Under the premise of guaranteeing the availability of the system, the optimization model of the total cost of the contract is as follows:

$$\begin{cases} \min K(T,W) \\ s.t. \\ A(T,W) \geq A_0 \\ C(T,W) \leq C_0 \end{cases}$$

A_0 are the military and civilian requirements for equipment or subsystem availability, C_0 is the upper limit of maintenance cost for the army and the people. Through consulting the literature, we found that grid search algorithm was used to solve the model and improve the accuracy of the model.

4. Application Analysis

Taking the upper part of 12 sub systems of a certain type of far fire equipment as an example, using the model built above, the cost model and the availability model of the maintenance cost support force of both the military and the civilian are calculated respectively. Finally, the change trend of the cost ratio of the two parties with the warranty period is finally obtained, and the comparison analysis is carried out on the graphics for maintenance and maintenance. The barrier of task differentiation provides data reference.

Regular preventive maintenance is carried out for a new type of equipment during the maintenance interval. The period of preventive maintenance is T days, the contract warranty period is W days, the preventive maintenance time of the contractor maintenance force is $T_{pa}=2$ days, the preventive maintenance time of the army maintenance and support force is $T_{pb}=3$ days, the repair time of the contractor maintenance force is $T_{fa}=4$ days, the repair maintenance time of the army maintenance support force is $T_{fb}=5$ days, and the contractor carries out the repair maintenance. The maintenance delay time caused by breach of contract is $T_{wa}=2$ days, the risk probability of the Contractor's repair default is $P_{wa}=0.1$, the delay time of the Contractor's logistics supply is $T_{ya}=7$ days, the risk probability of the contract merchant's logistical delay is $P_{ya}=0.15$, the contract merchant's repair maintenance cost C_{fa} is 1200 yuan, the Contractor's preventive maintenance cost is 1500 yuan, and the army repair maintenance dimension C_{pa} is 1500 yuan. The maintenance cost C_{fb} was 1200 yuan, the army preventive maintenance cost C_{pb} is 1300 yuan, the military maintenance support force and the civilian maintenance support force's availability requirement value A_0 was 0.9, and the maintenance cost ceiling of the military and the civilian maintenance support units was 70000 yuan.

On the basis of the above data, using the model algorithm mentioned above, the MATLAB software is used to simulate and optimize the cost and availability of maintenance cost and availability of remote fire equipment during the warranty period, and to calculate the changes with the warranty period, such as figure 1, figure 2, figure 3, and figure 4.

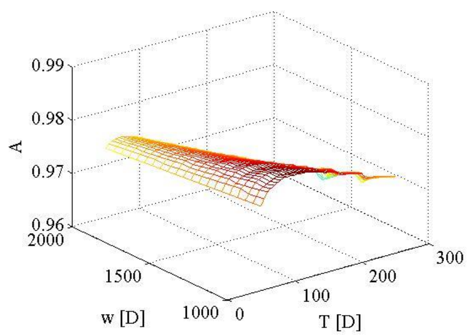

Figure 1. change trend of availability of maintenance support force

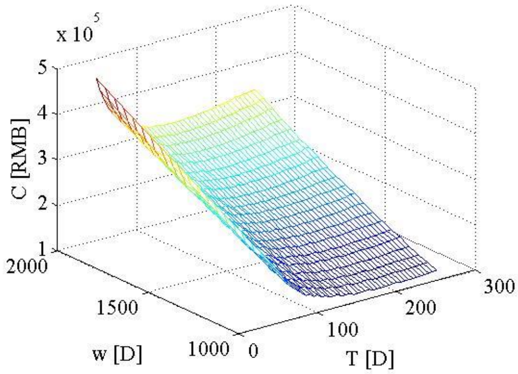

Figure 2. change trend of maintenance cost and maintenance cost of civil maintenance support force

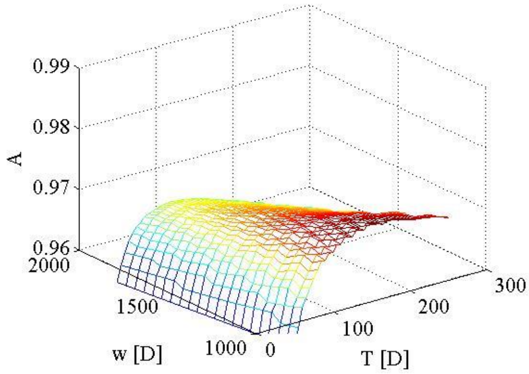

Figure 3. military maintenance support force availability trend chart

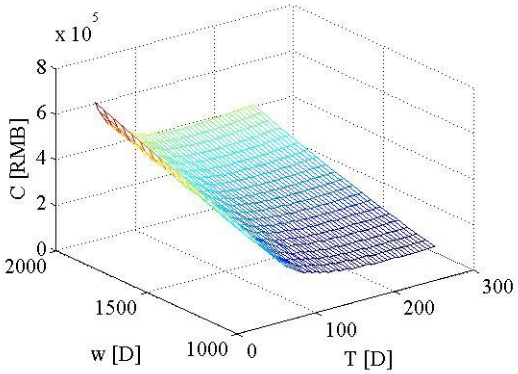

Figure 4. military maintenance support force cost change trend

The dimensionality reduction of the above simulation results is reduced with the warranty period, and the warranty cost increases with the warranty period, as shown in Figure 5, figure 6. From figure 7, figure 8, it can be seen that the maintenance support force of the people, compared with the military maintenance support, is more available at the same time in the warranty period, and decreases more slowly as the warranty increases.

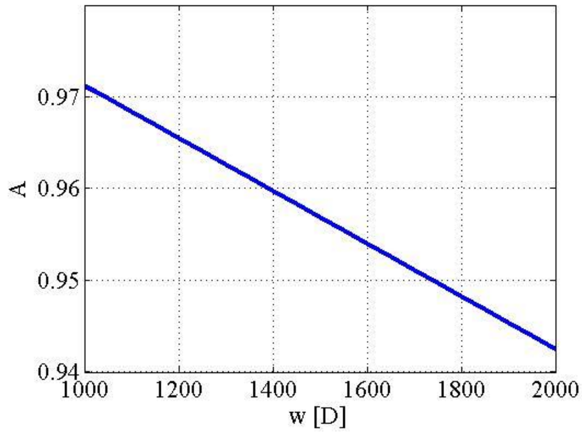

Figure 5. changes in the availability of the maintenance support force of the people's party

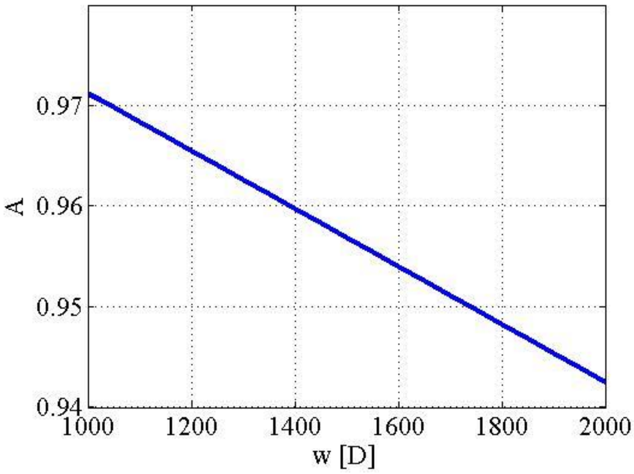

Figure 6. trend of availability of military maintenance support force

When preventive maintenance intervals are fixed, the availability of equipment will gradually decrease with the increase of warranty period. Among them, the warranty period is the same while the maintenance support force of the people is more efficient after maintenance.

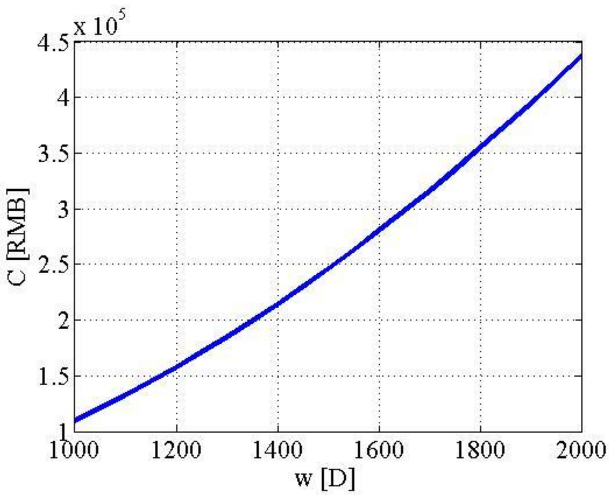

Figure 7. change trend of maintenance cost of maintenance support force

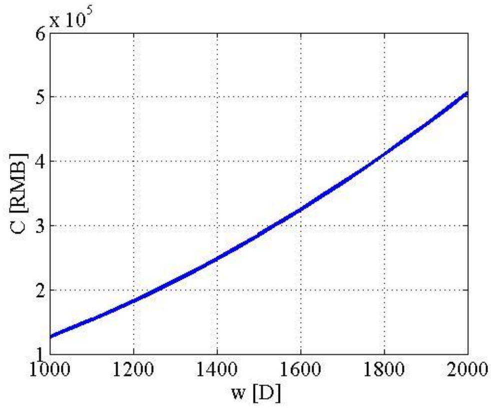

Figure 8. military maintenance support force maintenance cost change trend

It can be seen from the graph that when the preventive maintenance interval is fixed, the maintenance cost increases with the increase of warranty period. Among them, when the warranty period is determined, the cost of military maintenance support units is relatively low.

Set up 365 days per year, and according to the above analysis, the corresponding optimization results are obtained in different maintenance support contract periods. Part of the data are shown in Table 1.

Table 1. calculation results

Scheme	W/ days	T/ days	C_a / yuan	C_b / yuan	E_a	E_b	K_a	K_b
1	1095(3 years)	181	12400	11875	0.9776	0.9663	11.1635	11.2230
2	1460(4 years)	193	25124	24867	0.9622	0.9554	17.8842	17.8273
3	1825 (5years)	198	42387	41662	0.9512	0.9437	24.4173	24.1904

It can be seen from the table that with the increase of the warranty period and the interval of maintenance interval, the cost efficiency ratio of the maintenance and support units of the civilian and military is increasing, but the cost efficiency ratio of the maintenance support units of the people is lower than that of the military maintenance and support units. After fourth years, it begins to be higher than the military maintenance and support unit, indicating that the maintenance and maintenance of the civil service has just started. The unit cost maintenance efficiency of the barrier unit is higher, but with the increase of the warranty period, the military maintenance and support unit gradually becomes the maintenance support ability. Therefore, the maintenance guarantee should be made by the civil maintenance support unit in the maintenance period of 3 years. The maintenance guarantee period is 4 years and 5 years, the maintenance guarantee unit should be submitted to the military maintenance and support unit. Implement guarantee.

5. Conclusion

On the basis of analyzing the factors of the task differentiation, this paper establishes the cost and effectiveness model of the contractor and the force of the army, and then establishes the cost efficiency ratio model under the different maintenance strategies, which provides the basis for the decision. The results show that the method is scientific and effective, and it can provide certain reference for the task division of equipment maintenance support units. However, there are many factors affecting the problem. On the one hand, the decision to distinguish the problems should be qualitatively analyzed. On the other hand, it should be closely combined with the actual situation to make continuous revision and improvement.

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