Determination of optimal set of spare tools and supplies for national guard troops mobile workshop and choice of strategy for its replenishment

A N Pavlov, A N Gladkov, S N Goryashev

Perm Military Institute of National Guard Troops, Perm

E-mail: pal0707@mail.ru

Abstract. The strategy of emergency replenishment of spare parts is the most flexible. The strategy of periodic and continuous replenishment, in fact, is extreme cases. The determination of the optimal spare parts is made by using a step-by-step procedure, in which at each step the STS is added to the element selected by a criterion "reliability-cost". The procedure of forming the STS is completed.

1. Introduction

When using spare tools and supplies (STS), mobile workshop for maintenance and repair of computer equipment, a reconstruction equipment ACU military unit is reduced to the replacement of the failed module or parts of a workable spare part (SP).

Obviously, for economic reasons, the STS can not be unlimited, and there is the problem of determining the optimal spare part kit. Optimum implies such set of spare parts, which will ensure the required values of indicators of reliability of object technology ASU, and the cost of spare parts is minimal.

The kit is usually calculated for a certain period of operation, as in operation spare parts are consumed and must be replenished. There are different ways (strategies) to refill STS:

- periodic replenishment. The completion of SPTA until the desired composition is performed periodically with a predetermined period, TSIP. If it is necessary to repair, the item in the STS is missing (there is a "failure STS "), the system remains in this state until the next replenishment spare parts. Obviously, such strategy corresponds to the most stringent requirements for a spare part kit;

- emergency replenishment. In this case, the replenishment STS is also assigned. The difference lies in the fact that in the case of "opt- STS " made an emergency replenishment (EP) kit. The lag time in emergency replenishment STS TEP << T STS .

- continuous replenishment. With continuous replenishment of spare parts, object element equipment management information is replenished immediately after each failure. The delivery time for each refill is equal to TDCB.

The most flexible strategy is that of emergency replenishment of spare parts. The strategy of periodic and continuous replenishment, in fact, is extreme cases, a strategy for an emergency refill.
2. Materials and methods

The determination of optimal spare parts stock is made using a step-by-step procedure in which at each step, the STS is added to the element selected by the criterion "reliability-cost". The procedure of forming the STS finishes when the values of the reliability indices required a value [13].

Formulas for calculation of indicators of sufficiency of the different methods of replenishment of the spare parts are [3]:

1) periodic replenishment \((a=1)\). A group of similar items together with a STS in this case can be considered as a non-redundant system. The failure of the system occurs when reserve is exhausted (STS). Thus, the probability of sufficiency of spare parts for the i-th group of elements can be defined as the probability of failure of the system within the time equal to the replenishment period \(STS \ T\). If the system (the i-th group of elements) includes major elements \(ni\) and \(xi\) of the reserve elements, the probability of failure of the i-th group over time (life cycle) of \(T\) is equal to:

\[
P_{SPTA} \left( \frac{T}{a=1, x_i} \right) = P_{SPTA} \left( \frac{T}{x_i} \right) = 1 - I(A_i \cdot x_i + 1). \tag{1}
\]

where \(T\) is the period of replenishment spare parts;

\(A_i = n_i \gamma_i T\) - the average consumption of the elements of the i-th type at time \(T\);

\(I(A_i, x_i + 1)\) is a function of the gamma distribution, which is determined by the following expression:

\[
I(A_i, x_i) = 1 - \sum_{S=0}^{x_i} \frac{A_i^S}{S!} e^{-A_i}. \tag{2}
\]

Function \(I(A_i, x_i + 1)\) is the probability that during developments \(T\) refuse \(x_i + 1\) elements, the failure of which is independent and subject to exponential distribution with parameter \(n_i \gamma_i\).

For a non-repairable system, availability coincides with the probability of failure.

Therefore, the availability of the spare parts can be determined by averaging the probability of the replenishment period, the SPTA \(T\) will get:

\[
K_{a SPTA} (a=1, x_i, T) = \frac{1}{T} \int_0^T P_{SPTA} (t, x_i) dt = \frac{1}{T} \int_0^T (1 - I(n_i \gamma_i t) dt =
\]

\[
= 1 - I(A_i, x_i) + \frac{x_i + 1}{A_i} I(A_i, x_i + 1); \tag{3}\]

2) replenishment of emergency deliveries \((a=2)\). Since emergency deliveries are carried out after the failure of the system (group of elements), the probability of sufficiency of spare parts and emergency deliveries is also determined, as in the periodic replenishment [5]. The availability of spare parts and emergency deliveries is determined from the expression:

\[
K_{a SPTA} (a=2, x_i, T, T_{e d}) \approx 1 - (1 + e^{x_i}) \tag{4}\]

where \(T_{e d}\) - average duration emergency delivery;

3) continuous replenishment \((A_i=3)\). In the case of continuous replenishment, replenishment is made after each failure of the item included in the kit. The probability of sufficiency in this case, the ZIP is also determined by formula (9). The availability of spare parts is determined according to the following formula:

\[
K_{a SPTA} (a=3, x_i) = 1 - \frac{\gamma_i}{(x+1)} \sum_{s=0}^{x_i} \frac{\gamma_i^s}{s!} \tag{5}\]

where \(\gamma_i\) is TD securities as shipping each item is carried out from the Central database.

A simplified version of the SSN, an object technology ASU military unit used in the example shown in figure 1.
3. Conclusion

The most flexible strategy is that of emergency replenishment of spare parts. The strategy of periodic and continuous replenishment, in fact, in extreme cases, is a strategy for emergency refill. The determination of the optimal spare parts stock is made using a step-by-step procedure, in which at each step, the STS is added to the element selected by the criterion "reliability-cost". The procedure of forming the STS finishes when the values of the reliability indices require value [13]. Formulas for calculation of indicators of sufficiency of the different methods of replenishment of the spare parts are of the form [3]:

\[ \text{Figure 1. Structural diagram of reliability for service object technology of ACS in unit.} \]

\[ \text{Figure 2. The dependence of the value of STS on the total number of elements.} \]

\[ \text{Figure 3. The dependence of the coefficient of readiness on the total number of elements in the periodic replenishment of spare parts, } a = 1 \]
Figure 4. The dependence of the coefficient of readiness on the total number of elements in emergency deliveries of spare parts, a = 2

Figure 5. The dependence of the coefficient of readiness of the total number of elements for continuous replenishment of spare parts, a = 3

A part STS is sequentially the elements, the addition of which leads to a maximum increment of the reliability of complex technical means. After each step, an item is added, the user evaluates the adequacy of the achieved values of indicators of reliability and total cost of STS. As soon as they reach values of indicators of reliability and cost that meet the requirements of the user, the process of forming the STS finishes.

The results, obtained in this sample, provide insight into the process of formation of STS in different strategies of replenishment: any of them will be within the range limited by extreme strategies periodic - replenishment (worst case) and continuous replenishment (best case). On the basis of monitoring data, the personnel of the mobile workshop itself can decide on the rational composition of STS. If the predicted situation is more similar to the strategy for periodic replenishment (large distance from the CBA, the impossibility of faster delivery, for whatever reasons), then the critical factors influence the required spare part kit, with both factor and reliability requirements of object technology of ASU military units and cost constraints. Then the critical factors, influencing the required spare part kit, will be both factor and reliability requirements of object technology ASU military units and cost constraints. If there is predicted possibility of a relatively rapid delivery of spare parts from the Central Bank (a short distance, the availability of cheap vehicles, etc.), this situation is closer to the strategy of continuous replenishment. In this situation, the requirements for spare parts become less rigid, as quick delivery of a high level of reliability is provided at a much lower volume of STS. Thus, in conditions of continuous replenishment of availability factor, KG FROM ASU = 0.9996 is ensured already when the number of spare elements \( N_{zip} = 4 \). This significantly reduces the cost of STS STS = 2300.e.

The most flexible is the strategy of emergency replenishment of spare parts. The strategy of periodic and continuous replenishment is, in fact, in extreme cases, a strategy for an emergency refill.

The determination of an optimal spare parts stock is made using a step-by-step procedure in which at each step, the STS is added to the element selected by the criterion "reliability-cost". The procedure of forming the STS finishes when the values of the reliability indices required value.

References

[1] Antonov A V, Plyaskin A V 2003 Determination of the optimal number of spare elements of the system with constraints on cost. Reliability 4(7) 9-16

[2] Shura-Bura A E 1985 Reliability of technical systems. The directory. Chapter 14. Provision of technical objects, spare parts (M.: Radio and communication)

[3] Golovin I N, Kovrygin B V, Shura-Bura A E 1984 Design and optimization of replacement of items of electronic systems. (M.: Radio and communication)
[4] Cherkesov G N 2012 Evaluation of the reliability of the system given ZIP: proc. benefit. (SPb.:Bkhv-Peterburg)