Study on Optimization Allocation Models of Equipment Support Personnel

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***Abstract*—The support personnel are divided into three categories: operator, maintenance personnel and administrator. A state transition matrix is established combining with the training station, then the numbers of personnel can be solved. Support efficiency of personnel to task is defined, and optimization allocation model of support personnel is developed. An instance is get to analyze and prove the practicability of the model, finally.**

***Index Terms*—fsupport personnel, state transition, optimization allocation, model**

I. INTRODUCTION

As the main body of equipment security, the security personnel is the executor of the guarantee process, which directly affects the performance of equipment security. The reasonable configuration of the security personnel can enable the protection tasks to be completed in a timely and efficient manner, so that the equipment security can obtain the maximum benefits [1–4].

II. SECURE PERSONNEL DYNAMIC MODEL

A. Access Analysis for Security Personnel

1. Status of personnel exiting the system

In addition to the dynamic transfer within the system, it is also necessary to consider the situation of people entering and exiting the system $\mathbf{S}$. First define the number of security personnel at each state of the system at time t, which can be expressed as a vector

$$\mathbf{N}_A(t)=\left[N_{l_1}(t),N_{l_2}(t),N_{k_1}(t),N_{k_2}(t),N_{k_3}(t)\right] \quad (1)$$

Assuming that there is a state k4 outside the system $\mathbf{S}$, which represents the state of the security personnel exiting the system, it can be concluded that the exit probability of the personnel is

$$\begin{aligned}\mathbf{P}_{Sk_4}(t)&=\left[P_{l_1k_4}(t),P_{l_2k_4}(t),P_{k_1k_4}(t),P_{k_2k_4}(t),P_{k_3k_4}(t)\right]\\&=\mathbf{I}-\mathbf{I}\cdot\mathbf{P}_S(t)\end{aligned} \quad (2)$$

In the formula, $\mathbf{I}=\left[1,1,1,1,1\right]$.

Therefore, at time t, the vacancy caused by the withdrawal of personnel is

$$V_1(t)=\mathbf{N}_A(t)\left[\mathbf{P}_{Sk_4}(t)\right]^T \quad (3)$$

2. Security personnel access to the system

When security personnel become vacant, they need to be appropriately supplemented, that is, they need to have a certain number of personnel in the system. The status of personnel entering the system is divided into two categories: one is that people with certain security capabilities directly enter the system, and the other is that the newly assigned security personnel enter the system through pre-service training.

(1) Security personnel with certain security capabilities enter

People with the ability to secure access to the system $\mathbf{S}$ can be directly assigned to three categories of security personnel depending on their quality. Assuming that there is a state outside the system before entering the system, the state is defined as k_0. Then the probability of the security personnel entering the system directly can be expressed as

$$\mathbf{P}_{k_0S}(t)=\left[0,0,P_{k_0k_1}(t),P_{k_0k_2}(t),P_{k_0k_3}(t)\right] \quad (4)$$

In the formula, the first two items of the vector $\mathbf{P}_{k_0S}(t)$ are 0, indicating that they cannot enter the training state directly.

(2) Entry of security personnel trained in pre-job training

The newly assigned security personnel need to go through a preparatory training before they can take up the job. Therefore, there should also be a preparatory training state outside the system that enters the system $\mathbf{S}$. This state is defined as l_0. Then the probability of entering the system after preparatory training is

$$P_{l_0S}(t)=1-\mathbf{P}_{k_0S}(t)\mathbf{I}^T \quad (5)$$

In the formula, $\mathbf{I}=\left[1,1,1,1,1\right]$.

Obviously, a person who is in state l_0 at time t, and after joins the system the state k_i (i=1,2,3) is $P_{l_0S}(t)P_{l_0k_i}(t)$ ($i=1,2,3$) at time t+1, written as a vector form

$$P_{l_0S}(t)\mathbf{P}_{l_0K}(t)=[0,0,P_{l_0S}(t)P_{l_0k_1}(t),P_{l_0S}(t)P_{l_0k_2}(t),P_{l_0S}(t)P_{l_0k_3}(t$$

B. Dynamic Model of Security Personnel

Combining the above analysis, it can be seen that at time T, the number of security personnel in various states within the system S is expressed as a vector

$$\mathbf{N}_A(t)=\mathbf{N}_A(t-1)\mathbf{P}_S(t-1)+V(t-1)\mathbf{P}_{k_0S}(t-1)+V(t-1)P_{l_0S}(t-1)\mathbf{P}_{l_0K}(t-1) \tag{6}$$

Substituting type (3) into type (6) has

$$\begin{aligned}\mathbf{N}_A(t)&=\mathbf{N}_A(t-1)\mathbf{P}_S(t-1)+\left\{\mathbf{N}_A(t-1)\left[\mathbf{P}_{Sk_4}(t-1)\right]^T\right\}\mathbf{P}_{k_0S}(t-1)\\&+\left\{\mathbf{N}_A(t-1)\left[\mathbf{P}_{Sk_4}(t-1)\right]^T\right\}P_{l_0S}(t-1)\mathbf{P}_{l_0K}(t-1)\\&=\mathbf{N}_A(t-1)\left\{\mathbf{P}_S(t-1)+\left[\mathbf{P}_{Sk_4}(t-1)\right]^T\mathbf{P}_{k_0S}(t-1)+\left[\mathbf{P}_{Sk_4}(t-1)\right]^T P_{l_0S}(t-1)\mathbf{P}_{l_0K}(t-1)\right\}\end{aligned} \tag{7}$$

The above formula can be simply written as

$$\mathbf{N}_A(t)=\mathbf{N}_A(t-1)\mathbf{P}_1(t-1) \tag{8}$$

In type,

$$\mathbf{P}_1(t-1)=\mathbf{P}_S(t-1)+\left[\mathbf{P}_{Sk_4}(t-1)\right]^T\mathbf{P}_{k_0S}(t-1)+\left[\mathbf{P}_{Sk_4}(t-1)\right]^T P_{l_0S}(t-1)\mathbf{P}_{l_0K}(t-1)$$

Type (8), the first item represents training or direct adjustment within the system; The second is the adjustment of the direct transfer of personnel to the system to compensate for the vacancies that have been withdrawn; The third is the adjustment of personnel to the system through pre-service training to make up for vacancies that had been vacated. It can be seen that type (8) summarizes the dynamic laws of the security personnel, including entry, training, promotion, and exit, and can become the basis for the adjustment of equipment operators, equipment maintenance personnel, and equipment management personnel.

III. GUARANTEED PERSONNEL DYNAMIC OPTIMIZATION CONFIGURATION MODEL

Considering the differences in the three levels of security personnel in practice, that is, the ability of different levels of personnel to perform similar tasks is not consistent, which has a great impact on staffing, drawing on the Capability Maturity Model Integration, CMMI) method [5]. This article quantifies this impact as a guarantee of efficiency:

$$\eta_{ij}=\theta_{ij}\beta_{ij} \tag{9}$$

Of which:

η_{ij} –The guaranteed efficiency of the security staff at a certain time T, level I to complete the tasks in category J(the amount of time per person to complete the tasks).

β_{ij} –The ability factor of level I security personnel to perform category J security tasks;

θ_{ij} –Matching level I security personnel with category J security tasks.

Since the ability coefficient and compatibility of the security personnel are more subjective evaluation values, we can try our best to formulate evaluation criteria in conjunction with the actual practice, and use expert evaluation, AHP and other methods to evaluate. It should be noted that the score according to the evaluation criteria is based on the percentage system, and it also needs to be standardized and converted to belong to [0,1] The value inside, the standardized formula is:

$$w_k=\frac{Z_k-\overline{Z}}{S} \tag{10}$$

Among them, Wk is the standardized value; Zk is the kth evaluation score of a certain level of security personnel; $\overline{Z}$ is the average of the evaluation points of a certain level of security personnel; S is the standard deviation.

Competency coefficient evaluation determines the rating and scale scores of the various factors of the security personnel according to the job description:

The match degree evaluation is mainly divided into six scale levels according to the quality of the personnel and the degree of compliance with the protection tasks: complete conformity, basic conformity, conformity, sometimes conformity, non-conformity, and absence, followed by the following scale:

Assumptions:

(1) Persons in the training state are unable to complete the protection tasks;

(2) All security personnel in the same category have the same safeguard efficiency when completing the same safeguard task;

(3) When completing a certain safeguard task, the amount of tasks completed by each type of guarantor is proportional to its guarantee efficiency;

(4) The number of security personnel required for category j security tasks is Nj.

If there are currently n safeguard tasks, the number of k_i category security personnel assigned to the number j safeguard tasks at t time is $N_{k_ij}(t)$; There are the following modeling conditions

$$\begin{cases}\sum_{j=0}^{n}N_{k_ij}(t)\le N_{k_i}(t)\\ \sum_{i=1}^{3}N_{k_ij}(t)\eta_{k_ij}\ge n_j\\ N_{k_ij}(t)\ge 0;\ j=0,1,2...n;\ i=1,2,3\end{cases}$$

When considering the optimal staffing, you can directly consider the task of enabling the security personnel to complete the most efficient protection. The optimization model is expressed as

$$\max Z=\sum_{i=1}^{3}\sum_{j=0}^{n}N_{k_ij}(t)\eta_{k_ij} \tag{11}$$

This model is a linear programming model of total personnel constraints. In the process of solving the problem, it can be solved for the optimal solution and can be solved.

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