Equipment maintenance task prediction model analysis based on BAS-PSO hybrid optimization algorithm

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ABSTRACT
Aiming at the maintenance task prediction problem of armored forces, the macro model and micro model are established to analyze the constraint conditions, and the equipment maintenance task prediction model is established in order to meet the motor hours echelon storage. Under the condition of meeting the balance of annual motor hours payments, the motor hours consumed by equipment are allocated according to the annual training tasks, and a hybrid optimization algorithm of improved particle swarm optimization is designed to solve the model, and a case study is carried out on a few vehicles in a certain army. The simulation results show that the model can effectively solve the problem of equipment maintenance task prediction, and provide a reference value for troops to make the maintenance plans.

1. Introduction
As the core content of equipment management, equipment integrity rate is a key index to characterize the operational support effectiveness of equipment and to measure the combat effectiveness of troops Ma et al. (1994). The use of equipment refers to the process of changing the static state of equipment in order to achieve a certain military purpose, and is one of the important contents of the daily management of equipment. The essence of mobilization of equipment is: under the constraints of current equipment management regulations and systems, to meet the requirements of the annual training mission of the army is the traction, mainly based on the technical status information such as the motorcycle hour reserve of the equipment, and determine which equipment to use for each task according to a certain strategy, so as to determine the motor hours consumption rate of each equipment and the time for preventive maintenance. On the one hand, equipment utilization provides equipment for the completion of combat and training tasks. On the other hand, it takes the lead in leading the entire equipment support work, directly determining the time for preventive maintenance of equipment, and the time and quantity of spare parts and equipment. Ma and Chen (2000).

The current armored equipment deployment system of our army originated from the former Soviet Union. However, there are few theoretical studies on it. Bai Lijun firstly used the macro model to estimate the annual repair quantity of armor equipment by estimating the total annual consumption and the whole life, and then used the micro model to allocate the motor hours consumed by a single vehicle to achieve the annual optimal maintenance plan Bo et al. (2009). Mei Guojian studied the deployment strategy of armored equipment at the end of military service from three aspects of combat readiness demand, training demand, and maintenance ability. He believed that for armored equipment with a long service time, the use of combat readiness vehicles should be appropriately increased, the number of motor hours storaged for a single vehicle should be controlled, and the time of overhaul and medium repair should be delayed Zhang and Zhou (2019). Zhou Yunyan conducted research on the armored equipment in the early stage of service. By continuously adjusting the task allocation of the coaching vehicle, the motor hours of the coaching vehicle formed an echelon storage Wang et al. (2012). Liu Hongxiang introduced the management by objectives theory into the deployment management of armor equipment, but did not give specific deployment strategies Lin et al. (2016). Bi Zhandong takes vehicle scheduling optimization as the research goal and uses discrete modeling technology to build an armored vehicle scheduling model based on preventive maintenance.
2. Problem analysis

There is a strong coupling relationship between the annual maintenance plan and the mobilization plan of armored forces, so the maintenance plan is usually optimized with the mobilization plan. However, the overhaul of armored vehicles takes a long time. In order to avoid centralized repair, the annual repair plan should be made in advance. The preparation of the annual repair plan is based on the historical operation data and maintenance records of armored vehicles in the army, and the task prediction is made in combination with constraints such as maintenance interval mileage, vehicle demand for each month’s training tasks and maintenance ability, so as to determine the annual number of overhaul, medium and minor repairs Zareei et al. (2019). An overhaul is a thorough and comprehensive repair that is carried out when is needed or after a long interval mileage to restore the power, economy and reliability of the car, ensuring the perfect technical condition of the vehicle, and extend the service life of the vehicle. Medium repair is a balanced repair organized as needed after a certain mileage between the overhaul, which can promote the balance of the assemblies under unbalanced technical conditions, thereby rationalizing the economy and extending the interval mileage between vehicle overhauls. Minor repair is a kind of operational repair, which mainly eliminates hidden troubles or partial damages that occur during vehicle operation or maintenance operations. Some minor repair items can be estimated in advance according to natural wear rules or external signs of the assembly, and planned minor repairs can be organized intensively. Since the mobilization plan is made in advance, which is a prerequisite for the annual repair plan of armored vehicles, so the annual vehicle use situation should be considered when the repair plan is made.

Equally spaced maintenance cycles are adopted for equipment Wang et al. (2012), as shown in Figure 1. The equipment life cycle begins with a new or overhauled vehicle. New vehicles or overhauled vehicles are generally used as combat readiness vehicles. Once the motor hours storage falling below the lower limit of combat readiness storage due to the consumption for special reasons and exercises, the combat readiness vehicles will be converted into training vehicles for daily military training tasks. When the motor hours consumed by the equipment usage arrives at the time to carry out overhauls, medium repairs and minor repairs, the corresponding maintenance activities will be carried out. The length of overhaul cycles is 2 times to 4 times that of medium repair and minor repair cycles respectively. As shown in Figure 1, a minor repair is carried out every 150
Purpose of the algorithm: According to the annual military training tasks, the motor hours consumed in the planned cycle are reasonably allocated, so that the motor hours storage of all vehicles can form a echelon storage, and the vehicles to be overhauled and medium repaired can be generated as early as possible and put into rolling cycle use. From the perspective of the use of vehicles, the more vehicles are sent to repair at the same time, the fewer there are available vehicles. Once important tasks such as exercises occur, there will be difficulties in the deployment of vehicles. From the perspective of maintenance, sending more vehicles for repair at the same time is a great challenge to the maintenance organization. If the vehicles can't be repaired in time due to insufficient maintenance resources, the maintenance time will increase. As shown in Figure 2, the motor hours storage of 5 vehicles on the left are ‘echelon type’, and the right are ‘flat type’. Once the motor hours storage is flat type, the vehicles are in the same condition and will need to repair at the same time.

3. Conceptual analysis of maintenance plan

3.1. Balance of payments

As shown in Equation (1), $T_1$ represents the total number of motor hours planned to be consumed this year, $T_2$ represents the total number of motor hours produced through maintenance in the current year. When the two numbers are approximately equal, the constraint of ‘break-even’ is satisfied. Through the control of $T_1$, you can get an overview of the vehicles that need to be used this year. Through the right calculation of $T_2$, you can get the repair status of the vehicles in the current year. To meet the ‘break-even’ constraint, a troop can’t consume too many motor hours of vehicles at once, so as to maintain the overall readiness level. The motor hours are consuming, the motor hours are producing at the same time. In this way, the whole motor hours storage will maintain balance. ‘Estimated cycle hours consumed’ is the total number of cycle hours consumed by all vehicles in the year of completion of the mission.

The calculation method is as follows:

$$T_1 = \sum_{L=1}^{m} t_L$$  \hspace{1cm} (2)

$T_1$: Represents annual planned consumption of motor hours.
\( t_1 \): Represents the annual number of motor hours consumption of the \( L \)th vehicle.

\( m \): Represents the total number of armored vehicles in a troop.

‘Estimated cycle hours produced’ refers to the life of the new engine. The engine of the repaired vehicle must be replaced during the overhaul, which is refurbished during the medium repair. As restoring engine performance can produce motor hours, new motor hours will be produced after the overhaul and medium repair. If the engine is not changed, there will be no new motorcycle hours. Minor repair does not produce motor hours. The mathematical calculation formula is as follows:

\[
T_2 = \sum_{i=1}^{n} (x_{i1} \cdot t_{i1} + x_{i2} \cdot t_{i2})
\]

The meanings of the relevant symbols are as follows:

\( T_2 \): Represents annual planned production of motor hours.

\( x_{i1} \): Represents the annual quantity of vehicles sent to medium repair, returned to the troop and refurbished with engines.

\( x_{i2} \): Represents the annual quantity of vehicles sent for overhaul, returned and replaced with engines.

\( t_{i1} \): Represents the service life of the newly refurbished engine of an armored vehicle returned from medium repair.

\( t_{i2} \): Represents the service life of the newly installed engine of an armored vehicle returned from overhaul.

\( n \): Represents the total number of armored vehicles in a troop.

\( x_{i1} \cdot t_{i1} \): Represents the number of motor hours which medium repair produced.

\( x_{i2} \cdot t_{i2} \): Represents the number of motor hours which overhaul produced.

### 3.2. Percentage of consumption

The annual consumption of motor hours is mainly divided into two parts: training consumption and basic consumption. Training consumption refers to the consumption for training, such as field driving and shooting, which accounts for 90%. Basic consumption accounts for 10%, which includes 3 aspects. The first is the consumption in the process to and from the task. The second is reserved for driving test after repair. The third is for starting regularly to keep a vehicle in good condition.

### 3.3. ratio of combat readiness vehicles to training vehicles

The coaching vehicle and the combat preparation vehicle are interchangeable. Once a training vehicle is overhauled, it will be classified into a combat readiness vehicle. When a combat readiness vehicle’s motor hours storage decreases to a certain level, it will become a training vehicle. However, in a troop, training vehicles account for 60%, which consume the largest number of motor hours. Combat readiness vehicles account for 40%. Usually, combat readiness vehicles are not used for training, but are started about two hours a month regularly.

### 4. Constraint analysis

#### 4.1. Constraints between the annual planned consumption and the annual cycle hour limit

The annual motor hours quota issued by the superior represent the maximum usage of the vehicle in a year, which cannot be exceeded. However, the usage amount can’t be decreased heavily, which will affect the completion of the annual task. From the perspective of business process, it is necessary for the training department and the maintenance department to fully interact, plan the annual training work reasonably, make the motor hours consumption plan, make full use of the vehicles within the motor hours quota, to complete annual tasks. The problem is how to determine the number of motor hours required to complete the tasks of the troop, not exceeding the consumption quota issued by the superior.

#### 4.2. Constraints between annual planned consumption and annual planned production

The annual quota for consumption of motor hours and the annual estimated production of motor hours should be roughly the same, which is commonly referred to as ‘balance of payments’. It is important to keep this balance, so as to maintain the level of combat readiness vehicles. The annual motor hours production depends on the maintenance capabilities. It must be appropriate. If the production is more then the consumption, there will be more vehicles sent to repair, which not only making the repair task too heavy, but also affecting the deployment of vehicles. If the production is less than the consumption, the motor hours storage will decrease, affecting the combat readiness of a troop. So, it is important to plan the production and consumption in a balanced way.

#### 4.3. Constraint of equipment technical state layout principle

In order to achieve the target of ‘planned use and balanced repair’, the use categories of training vehicles are usually strictly distinguished, and they are divided into
three categories according to the degree of use: key vehicles, general vehicles and control vehicles, with roughly the same proportions. Prioritize the use of key vehicles, so as to consume motor hours as soon as possible, meet maintenance standards, and send them for overhaul and medium repairs. The general car is used when the key car cannot be satisfied. After the key vehicle is sent for repair, the general vehicle is converted to the key vehicle, and the control vehicle is converted to the general vehicle. The division of training vehicles is shown in Table 3.3 below.

5. Forecast model of armored vehicle annual maintenance task

5.1. Develop process analysis

The annual task prediction model of armored vehicle refers to a mobilization plan, which is composed of repair plan and use plan. The repair plan is to determine the annual quantity of repair according to the total annual consumption and the total motor hours storage, that is, the macro model. The use plan is to allocate usage hours of every vehicle according to the annual repair quantity and annual training tasks, namely the micro model Ma et al. (1994).

The macro model is to determine the quantity of repair according to the relationship among the motor hours, annual training plan and maintenance resources. The relevant constraint conditions are shown in Figure 3.

The micro model is to determine the number of motor hours consumed by a single vehicle, according to the number of annual repair and the total number of cycle hours planned to be consumed, with the target of ‘planned use and balanced repair deliveries’. The micro model is built on the basis of the macro model, and the macro model will also be adjusted according to the results obtained from the micro model. The total annual planned consumption of motor hours can be obtained through the basic consumption and training consumption. According to the balance of payments theory, the annual planned production of motor hours can be obtained, and then the quantity of overhaul and medium repair can be obtained. According to the micro model, the annual planned consumption of motor hours is allocated to the each vehicle, and the established mathematical model is calculated by integer programming to charge whether the annual repair quantity is consistent with the results from the macro model. If not, the use plan is constantly adjusted until a reasonable repair quantity is obtained. Constraint conditions related to the microscopic model are shown in Figure 4.

This paper shows the process of make repair plan, including the total quantity, the vehicle to be repaired, the repair type, and repair time, according to the macro model. The micro model is applied, to make the use plan. First, according to the motor hours storage of the training vehicles, three use degree of vehicles are divided, and the vehicles to be repair this year are determined. Then, according to the process of the micro model, under the condition of meeting the consumption ratio of training vehicles and combat readiness vehicles, combined with the technical status of training vehicles at the beginning of this year, the total annual consumption of motor hours can be allocated to the each vehicle in each month. Maximum number of vehicles to medium repairs and overhaul this year is also determined. The key to make the repair plan is to meet the ‘balance of payments’ of motor hours. The number of vehicles to be sent for repair and the level of repair can be determined through the equal relationship between the planned consumption and the estimated production. Figure 5 shows the annual repair plan formulation flow chart.
5.2. Model assumptions

Hypotheses: (1) An armor detachment has one new type of track-type armored vehicle A, and the service life of the engine is $M$ hours. All the vehicles have been classified into combat readiness vehicles and training vehicles, and the training vehicles are classified into key vehicles, general vehicles and control vehicles.

(1) Annual motor hours consumption is known: according to the annual military training plan, the number of planned motor hours consumption in each month is determined, and then the motor hours allocated by the cycle plan are determined.

(2) The number of remained motor hours at the beginning of the year and the estimated repair level of each vehicle are known: according to the remained motor hours at the beginning of the year and theory of dividing three types of vehicles, the number and month-time of scheduled repair for key vehicles, general vehicles and controlled vehicles can be determined.

(3) The optimization target of this model is to achieve the echelon storage of the motor hours, avoid the occurrence of a large number of vehicles sent to repair at the same time, and reduce the waste of maintenance resources. By making a reasonable use plan, the vehicles can be used reasonably, and the motor hours storage of armored vehicles can meet the standard. Thus, in the event of a force emergency, the number of vehicles available can be maximized so that there is no shortage.

$$\min \sum_{j=1}^{J} \sum_{i=1}^{I} \left[ E_{ij} - a_{ij} - \frac{H}{I_2} (i - I_2) \right]^2$$

$$c_{ij} \leq a_{ij} \leq b_{ij}, \forall i, j \in J$$

$$\sum_{i=1}^{I} t_{ij} \leq R_{ij}, \forall j \in J$$

$$E_{i1} \geq \sum_{j=1}^{T} t_{ij}, \forall i \in I, x \in X, l \in L$$

$$\sum_{j=5i}^{T} t_{ij} = 0, \forall i \in I_2$$

$$0 < E_{i2} - \sum_{j=1}^{T} a_{ij} < R_j, \forall i \in I_2, x \in X$$

Tables 1–2 shows the sets, subscripts and parameter definitions used in the model. The actual meaning represented by each constraint condition is as follows: Formula (5) represents the constraint on the number of motor hours planned to be consumed by the vehicle each month. For basic maintenance, each vehicle must be started a few hours each month regularly, so each vehicle will have planned minimum consumption of motor hours per month. In addition, training tasks cannot be centrally allocated to vehicles which motor hours remained...
behavior of birds and belongs to a kind of swarm intelligence optimization algorithm. It has the advantages of fast search speed, high efficiency and simple algorithm, but for discrete optimization problems, it is easy to fall into local optimum Peschiera et al. (2020). Therefore, the performance of traditional particle swarm optimization algorithm can be improved by introducing inertia weight, designing different topology structures or combining with other optimization algorithms. Assume that the number of N particles in the D dimensional space is, the position of particles \( i \) is \( x_i = (x_{i1}, x_{i2}, \ldots, x_{iD}) \), and the velocity is \( v_i = (v_{i1}, v_{i2}, \ldots, v_{iD}) \). According to the fitness function, the historical optimal position of particles is \( p_i = (p_{i1}, p_{i2}, \ldots, p_{iD}) \) and the optimal position of all particles is \( p_g = (p_{g1}, p_{g2}, \ldots, p_{gD}) \) in the population are obtained.

The formula for updating the speed and position of each particle is as follows:

\[
\begin{align*}
\dot{v}_{id}^{k+1} &= w \cdot v_{id}^{k} + c_1 \cdot r_1 \cdot (p_{id}^{k} - x_{id}^{k}) + c_2 \cdot r_2 \cdot (p_{gd}^{k} - x_{id}^{k}) \\
x_{id}^{k+1} &= x_{id}^{k} + v_{id}^{k+1}
\end{align*}
\]

Where, \( c_1 \) and \( c_2 \) is the learning factor, that is, the maximum stride length of adjusting learning, which is generally constant; \( r_1 \) and \( r_2 \) is a random number between, to increase the randomness of the search; \( w \) is inertia weight, which adjusts the searching ability of solution space; \( k \) is the number of iterations. Figure 6 is a schematic diagram of the adjustment of particle velocity and position in the \( t \)-th generation and the \( t+1 \)-th generation, where \( \bullet \) is the global optimal solution.

### 5.3.2. Beetle Antennae Search (BAS)

BAS algorithm is a new multi-objective function optimization intelligent algorithm proposed by Jiang et al. Jensj and Jiji (2016) in 2017. In the algorithm, beetle position is defined as the solution of the problem to be solved, and food represents the optimal solution of the problem. When the beetle hunts, it has two antennae that sense the intensity of the smell the food gives off.

Depending on the smell of its antennae, the beetle changes its flight direction and eventually finds its food.

The standard BAS defines only one type of beetle. It learns local information to update its flight direction. Therefore, the algorithm has the characteristics of small computation, fast optimization speed and good local optimization performance. The simple model diagram of BAS is shown in Figure 7.

### 5.3.3. BAS – PSO algorithm

It must be combined with particle swarm to improve the ability of global search and local search effectively. Each

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**Table 1. Training vehicles division standard**

| Training vehicles type | Motor hour remain |
|------------------------|------------------|
| Key car                | less than 160    |
| General car            | 160 ~ 260        |
| Control car            | more than 260    |

**Table 2. Sets, subscripts and parameter definitions used in the model**

| Symbol | Define |
|--------|--------|
| \( I \) | Total number of training vehicles |
| \( I_2 \) | Total number of key vehicles |
| \( I_y \) | The total number of general vehicles |
| \( S_j \) | Months in which the \( j \) vehicle is being repaired |
| \( X \) | Sum of maintenance level types |
| \( L \) | Sum of training vehicle types |
| \( T \) | All the months |
| \( f \) | Sum of repair months |
| \( B_j \) | Plan to consume total motor hours in the \( j \)-month |

**Parameter**

| Symbol | Define |
|--------|--------|
| \( b_{ij} \) | The \( i \) vehicle and the \( j \)-month of the motor hour usage cap |
| \( c_{ij} \) | The \( i \) vehicle and the \( j \)-month of the motor hour usage cap |
| \( a_{ij} \) | The motor hours planned for the \( j \)-month and the \( i \) vehicle |
| \( t_{ij} \) | The motor hours actually consumed for the \( j \)-month and the \( i \) vehicle |
| \( E_d \) | The \( i \) vehicle of the \( t \)-type has the number of motor hours remained at the beginning of the year |
| \( H \) | Key vehicles and motor hours storage lower limit |

are few, should be allocated reasonably. So setting the maximum motor hours consumption limit is necessary, not exceeding the total planned monthly consumption of all vehicles. Equation (6) indicates that the total number of motor hours consumption actually allocated for the training vehicles each month cannot exceed the total number of motor hours expected to be consumed at the beginning of the month. Equation (7) indicates that the motor hours each training vehicle actually consumed can’t exceed the number of motor hours its remaining at the beginning of a year. Equation (8) indicates that on training tasks will be assigned to key vehicles after they are sent to repair. Formula (9) indicates that key vehicles, general vehicles meet the standard of rotation.
Figure 6. Adjustment of particle's speed and position

Figure 7. Simplified model of BAS

Particle in the particle swarm is equivalent to a longhorn beetle. In the iteration process, the fitness function value on the left and the right side is compared, and the better value is used to update the position of longhorn cattle, so as to improve the global search ability and prevent falling into the local optimum. Moreover, the local search ability of the particle swarm optimization algorithm is better.

In summary, the specific steps based on longicorn whisker combined with particle swarm optimization algorithm are as follows:

Step 1: Parameter initialization. The position $V_i$ and velocity $X_i$ of the individual, the maximum number of iterations $K$, the step size factor $\delta$, the upper $V_{\text{max}}$ and lower $V_{\text{min}}$ bounds of the velocity.

Step 2: Calculate individual fitness function value.

Step 3: Set the weight according to formula (11).

Step 4: For each particle in the population, calculate the fitness function values of the left and right antennae according to formula (12) and formula (13).

$$X_i(t + 1) = X_i(t) - V_i(t) \ast d/2 \quad (13)$$

According to formula (4), the regeneration position of individual longicorn was calculated $\xi$:

$$\xi_i(t + 1) = \delta(t) \ast V_i(t) \ast \text{sign}(f(X_r^i(t)) - f(X_l^i(t))) \quad (14)$$

According to formula (5), the individual speed of longicorn was calculated:

$$V_i(t + 1) = wV_i(t) + c_1r_1(P_i^j(t) - X_i^j(t)) + c_2r_2(P_g^j(t) - X_g^j(t)) \quad (15)$$

According to formula (6), the position of individual longicorn was calculated:

$$X_i(t + 1) = X_i(t) + \lambda V_i(t) + (1 - \lambda)V_i^j(t) \quad (16)$$

Step 5: Calculate individual fitness function value, record and save current individual position.
For each particle in the group,
\[ f(x) = \begin{cases} f_{pbest} & \text{if } f(x) < f_{pbest} \\ f_{gbest} & \text{if } f(x) > f_{gbest} \end{cases} \] (18)

Step 6: update the location of the optimal solution.
Step 7: judge whether the iteration termination condition is satisfied. If it is satisfied, the iteration will terminate and output the optimal solution. Otherwise, jump to step 4 and continue the iteration..

5.3.4. Algorithm performance test
In order to verify the effectiveness of BAS PSO algorithm, two single peak functions and two multi-peak functions are selected to test the minimum value of the function.

1) Sphere model
Function expression:
\[ f_1(x) = \sum_{i=1}^{n} x_i^2 \] (18)
Global optimal value:
\[ \min f_1(x) = 0 \] (19)

2) Schwefel’s Problem
Function expression:
\[ f_2(x) = \sum_{i=1}^{n} |x_i| + \prod_{i=1}^{n} x_i \] (20)
Global optimal value:
\[ \min f_2(x) = 0 \] (21)

3) Generalized Rosenbrock
Function expression:
\[ f_4(x) = \sum_{i=1}^{20} [x_i^2 - 10 \cos(2\pi x_i) + 10] \] (22)
Global optimal value:
\[ \min f_4(x) = 0 \] (23)

4) Generalized Rastrigin
Function expression:
\[ f_4(x) = \sum_{i=1}^{n} [x_i^2 - 10 \cos(2\pi x_i) + 10] \] (24)
Global optimal value:
\[ \min f_4(x) = 0 \] (25)

5.3.5. Test result
The initial condition is that the number of particles is 20, the maximum number of iterations is 1000, and the dimension of each particle is 10.

Test conclusion: from Figures 8–11 above, we can know that the above two algorithms can obtain the optimal solution only for unimodal function and non-ill-conditioned equation. The more iterations and the more population, the higher the accuracy will be, but it will also...
prolong the operation time, so the iterations and population need to be set well, and relatively speaking, the particle swarm optimization algorithm with linear decreasing inertia weight finds the best solution. For multimodal function, the accuracy of the above two algorithms is very different whether increasing the number of iterations or the number of population. So, we can conclude that the ba-spso algorithm has a significant effect, and the algorithm is essentially changed, which accuracy is also improved a lot.

6. Application case analysis of the model

Assume that an armored unit has 30 armored vehicles, and the limit for each vehicle is 30 motor hours. The proportion of training vehicle consumption is 90%, that is, the total annual consumption is 810 motor hours, and it is divided into key vehicle, general vehicle and control vehicle. Table 3 shows the number of moto hours remaining for each training vehicle at the beginning of a certain year. According to the annual military training plan, the planned monthly consumption of motor hours is obtained, as shown in Table 4. Through the simulation, the allocation scheme of motor hours for each vehicle is obtained, as shown in Table 5.

According to the annual allocation scheme of motor hours in Table 5, combined with the remaining motor hours of each vehicle at the beginning of year and the maintenance interval at all levels, the annual repair plan can be obtained. As can be seen from Table 6, No. 1, No. 2 and No. 3 vehicle are sent to medium repair respectively, and the number of motor hours produced after

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**Table 3. Hourly Reserves of Coach Car Motorcycles at the beginning of the Year**

| type       | number | KEY VEHICLES | general vehicle | control vehicle |
|------------|--------|--------------|-----------------|-----------------|
| Remaining  |        | 16           | 54              | 76              |
|            |        | 3            | 237             | 242             |
|            |        | 242          | 287             | 350             |
|            |        | 397          | 450             |                 |

**Table 4. Estimated monthly consumption of motorcycle hours table**

| mouth      | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| hours      | 10    | 20    | 100   | 100   | 110   | 110   | 100   | 70    | 80    | 100   | 20    | 10    |

**Table 5. battalion's annual equipment motorcycle hour allocation plan**

| Equipment/Month | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | sum |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| 1              | 2     | 2     | 11    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 15  |
| 2              | 2     | 2     | 10    | 10    | 10    | 10    | 10    | 0     | 0     | 1     | 0     | 55   |     |
| 3              | 2     | 2     | 10    | 10    | 10    | 10    | 10    | 5     | 8     | 8     | 0     | 75   |     |
| 4              | 1     | 4     | 17    | 13    | 19    | 10    | 19    | 14    | 13    | 8     | 3     | 122  |     |
| 5              | 0     | 2     | 8     | 20    | 32    | 26    | 10    | 8     | 13    | 8     | 3     | 3    | 133  |
| 6              | 0     | 0     | 12    | 14    | 14    | 24    | 19    | 11    | 15    | 17    | 1     | 2    | 129  |
| 7              | 1     | 2     | 1     | 11    | 3     | 0     | 13    | 5     | 11    | 21    | 3     | 1    | 72   |
| 8              | 1     | 1     | 15    | 7     | 20    | 10    | 0     | 6     | 14    | 8     | 3     | 2    | 87   |
| 9              | 0     | 4     | 2     | 6     | 2     | 15    | 3     | 10    | 3     | 15    | 3     | 1    | 64   |
| 10             | 1     | 1     | 14    | 9     | 0     | 5     | 16    | 11    | 3     | 15    | 3     | 0    | 38   |
| sum            | 10    | 20    | 100   | 100   | 110   | 110   | 100   | 70    | 80    | 100   | 20    | 10   |     |
Table 6. Annual Repair Schedule

| Equipment/ Month | 1     | 2     | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | sum |
|------------------|-------|-------|----|----|----|----|----|----|----|----|----|----|-----|
| 1                | medium repair | | | | | | | | | | | | |
| 2                | medium repair | | | | | | | | | | | | |
| 3                | medium repair | | | | | | | | | | | | |
| 4                | medium repair | | | | | | | | | | | | |
| 5                | medium repair | | | | | | | | | | | | |
| 6                | medium repair | | | | | | | | | | | | |
| 7                | | | | | | | | | | | | | |
| 8                | medium repair | | | | | | | | | | | | |
| 9                | | | | | | | | | | | | | |
| 10               | | | | | | | | | | | | | |
| 11               | | | | | | | | | | | | | |
| sum              | | | | | | | | | | | | | |

each medium repair is 375 h, and the total number of 825 motor hours produced during the three medium repairs is roughly equal to the annual planned consumption of motor hours, so the annual balance of income and consumption of motor hours is satisfied. Overhaul, medium and minor repairs occur randomly and are determined jointly by the remaining motor hours and the utilization of the vehicle at the beginning of the year. Although there are no overhaul in this model, the obtained results meet the income and consumption balance of the motor hours, so this model is feasible to a certain extent.

7. Conclusions

In this paper, the optimization model of the annual vehicle maintenance plan was studied by comprehensively considering the utilization and maintenance of the vehicle, so as to meet the hourly echelon storage target of the motor hours. The prediction model of the annual vehicle maintenance task was established, and the solution scheme of the BAS-PSO hybrid optimization algorithm was designed. The simulation results show that the model can reasonably allocate the motor hours consumption according to the annual training tasks of the vehicle, coordinate the maintenance resources and the regulations and other constraints, maximize the military effectiveness of the vehicles, and send the vehicles to repair scientifically. However, this paper only considers part of the equipment of the army, and the next step is to start from the whole army and optimize the equipment sending and repairing plan of the whole army.

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