

# Research on optimization of Dispatching System of Military Disaster relief Material Transport Vehicles

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**Abstract:** With the rapid development of informatization, a more efficient dispatching system is needed in the process of military logistics and transportation management to provide guarantee for emergency needs. From China's point of view, in the face of natural disasters, the military's participation in rescue is a common guarantee task. How to optimize the effective vehicle scheduling in the process of specific disaster relief material transportation is of great significance to promote the timeliness and effectiveness of rescue. This article establishes a vehicle scheduling model based on time windows by combining the characteristics of emergency transportation, in order to function by the time function, and can be solved by using genetic algorithm, according to the example analysis algorithm in overcome the problem of convergence time, can effectively promote the transportation vehicle scheduling, relief materials transportation scheduling decisions about the army have corresponding reference value.

**Keywords:** Army; Emergency transport; Vehicle scheduling; Genetic algorithm (ga).

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## 1. Introduction

In recent years, natural disasters have occurred frequently, posing a serious threat to the safety of people's lives and property. In the emergency response process of natural disasters in our country, it is often jointly carried out by the government and the military, facilitating timely rescue of personnel and property. The supply of disaster relief materials plays a crucial role in the effectiveness of rescue efforts, with the transportation of disaster relief materials primarily serving the purpose of transportation needs during natural disasters, public events, and similar exigencies. It is based on the military and social transportation facilities, striving to minimize special transportation activities within the shortest time frame and minimize disaster losses [1]. In the face of natural disasters, the military can rapidly respond to demands under organized command, swiftly undertake corresponding tasks, play a major role in rescue transportation, and demonstrate its practical capabilities in emergency environments.

Vehicle Scheduling (VS) mainly refers to the rational scheduling of vehicle resources based on user demand when the number of vehicles increases to a certain extent. It aims to reduce costs during transportation while meeting user demand, thus obtaining the optimal scheduling scheme. In the process of transporting disaster relief materials, vehicle scheduling is a critical link, requiring improvement in transportation efficiency and striving to seize the golden rescue time, thereby achieving precise rescue. With the frequent occurrence of global natural disasters in recent years, scholars both domestically and internationally have paid significant attention to the research of emergency transportation vehicle scheduling. Domestic scholars such as Shao Zejun, Chen Fanhong, etc. [2] have proposed that communication interruption in disaster areas and the destruction of transportation networks are the most important factors affecting vehicle scheduling problems in the process of material transportation. Yuan Jinsha, Ma Zi, etc. [3] have

constructed corresponding vehicle scheduling models based on the types of rescue materials and road conditions, and verified the effectiveness of the models through practical cases. Wang Fuyu, Chen Jingjing, etc. [4] believe that priority should be given to demand in the process of constructing emergency vehicle scheduling models, and have built corresponding models based on this viewpoint. Özdamar [5], based on dynamic analysis of supply and demand, analyzed the emergency transportation problem of material supply and proposed a goal function of minimizing transportation time. Korosec [6] studied the scheduling problem with high port loading and unloading frequencies, tested it through organized and free transportation methods, and discussed the optimization direction of different transportation modes, which has a certain guiding role in promoting the optimization research of emergency transportation vehicle scheduling for disaster relief materials.

In the process of natural disaster relief, the transportation of relief supplies exhibits characteristics such as timeliness and economic constraints. Therefore, the specific scheduling process demands urgency and relatively low costs to ensure the timely completion of transporting relief supplies. From the perspective of the military, missions during non-wartime periods are also goal-oriented, with economic factors not being the primary consideration. Thus, they share common objectives with emergency transportation. Consequently, the military possesses significant advantages in executing emergency transportation tasks for relief supplies. Based on this premise, this paper constructs a military relief supply transportation vehicle scheduling model based on time windows, focusing solely on the urgent objective of time, enhancing traditional genetic algorithms by incorporating emergency vehicle grouping, and verifying the effectiveness of the algorithm through case studies.

## 2. Problem Description and Model Construction

Drawing on practical analyses of emergency relief supply transportation in natural disaster contexts in recent years in China, the problem description for military relief supply vehicle scheduling amid natural disasters is as follows: After a natural disaster occurs, it is necessary to investigate and analyze the affected areas, urgently tally and allocate necessary relief supplies. Here, the affected areas are represented by  $i(i=1,2,\dots,n)$ , with varying demand for supplies at different sites represented by  $G_i(g_1, g_2, \dots, g_n)$ . Under the coordination of relevant authorities, military transportation units respond by dispatching fleets as per requirements to transport relief supplies. The number of fleets is denoted by  $k(k=1,2,\dots,K)$ , with each fleet has  $L$  vehicles. Each fleet must act according to requirements, proceed to load supplies from storage locations, deliver them to designated disaster sites based on established plans, and finally return to their base.

Based on the above analysis, a model is constructed. To facilitate model construction, the following assumptions are proposed, along with definitions of relevant parameters:

(1) Each disaster-stricken site is supported by a single fleet; (2) The loading and unloading time of each fleet is denoted as  $T_x$ ; (3) Due to differences in the disaster situation, different disaster sites have corresponding requirements for the arrival time of supplies. Therefore, a latest arrival time is set, represented as  $[0, LT_i]$ ; (4) The uniform speed of fleet travel is  $V$ ; (5) Each vehicle can carry a load of  $Q$ ; (6)  $R_k = \{r_{k1}, r_{k2}, \dots, r_{kn_k}\}$  represents the set of paths traversed by fleet  $k$  in a vehicle scheduling scheme,  $n_k$  represents the number of disaster-stricken sites supported by fleet  $k$ , i.e., the number of elements in  $R_k$ ;  $r_{km}$  is an element in the path set  $R_k$ , indicating the sequence of disaster-stricken point  $r_{km}$  in the path set  $R_k$  as  $m$ , with  $r_{k0} = 0$  representing the material reserve depot, and  $rk(nk1)$  representing the transportation overnight stop; (7)  $d_{ij}$  represents the distance between points  $i$  and  $j$ , using decision variable  $x_{ijk}$  to represent fleet  $k$  departing from point  $i$  to reach point  $j$ , where points  $i$  and  $j$  include the material reserve depot point 0 and the transportation overnight stop point  $n+1$ ;

$$x_{ijk} = \begin{cases} 1 & \text{车队}k\text{由点}i\text{行驶到点}j \\ 0 & \text{其他} \end{cases}$$

车队  $K$  由点  $i$  行驶到点  $j$ : Convoy  $K$  traveling from point  $i$  to point  $j$

According to the objective function, under the condition of time requirements, the shortest distance for transporting vehicles is required. In the following formula (1),  $L$  represents the number of vehicles in the fleet,  $S$  represents the mileage, and  $P$  is the penalty function:

$$\min Z = L \cdot S + P \quad (1)$$

Where:

$$S = \sum_{i=1}^{n+1} \sum_{j=1}^{n+1} \sum_{k=1}^k x_{ijk} d_{ij} \quad (2)$$

$$P = \alpha \sum_{i=1}^n \max\{0, T_i - LT_i\} + \beta Viol \quad (3)$$

$\alpha$  and  $\beta$  are penalty coefficients,  $\alpha$  is the penalty coefficient when the fleet exceeds the total specified time, and  $\beta$  is the penalty coefficient for the number of fleets exceeding the specified time.  $Viol$  represents the number of points exceeding the specified time among all disaster-stricken sites. It assumes that  $L_k$  in the function represents the number of vehicles in the  $k$ -th fleet, the minimum total mileage of vehicle transportation in the scheduling scheme can be calculated, which can minimize costs to the greatest extent but may increase transportation time relatively. After calculating the vehicle transportation scheduling scheme based on timeliness, the issue of whether there are empty vehicles in the fleet is analyzed, and unnecessary vehicles are reduced as much as possible to reduce costs while ensuring the completion of the target task within the shortest time range. The specific model constraint conditions are as follows:

$$\sum_{k=1}^k \sum_{j=1}^n x_{ijk} = 1 \quad (4)$$

$$\sum_{k=1}^K \sum_{j=1}^n x_{ijk} = 1 \quad (5)$$

$$\sum_{m=1}^{n_k} G_{r_{km}} \leq Q \quad (6)$$

$$\sum_{k=1}^K n_k = n \quad (7)$$

The constraints from the above formula (4) indicate that only one fleet departs from the demand point; formula (5) indicates that only one fleet reaches the target disaster site; formula (6) states that when the fleet passes through the disaster point, the demand is less than the load; and formula (7) indicates that the transportation and distribution of supplies to each disaster site meet the demand.

## 3. Model Solution Based on Improved Genetic Algorithm

In the optimization process of disaster relief vehicle transportation scheduling, as the number of disaster points increases, the number of combinations to solve the model will also show a geometric growth, making the solving process quite challenging. When facing the computation of solving large-scale vehicle transportation scheduling problems, exact algorithms involve massive computations and are thus highly challenging. Therefore, in practical applications within academia, heuristic algorithms are mostly adopted, including mixed genetic algorithms, immune algorithms, and so forth.

Combining the above model analysis, this paper proposes improvements to traditional genetic algorithms to enhance timeliness and avoid solving local problems. Specifically:

(1) In the genetic algorithm, genes represent the solution to the problem at hand. For the disaster relief material transportation vehicle dispatching problem, the fleet scheduling scheme can be referred to as a chromosome, with multiple chromosomes constituting a population. In this model, the corresponding solution chromosomes mainly consist of two segments: DNA\_1=[dna1, dna2, ..., dn] for sequencing the disaster points and DNA\_2=[dna1, dna2, ..., dna(K-1)] as breakpoint sequences to differentiate between different fleet routes, where the assembly position index is 0, and the transportation troop bivouac index is n+1.

Considering the above model and problem analysis, after receiving task orders, fleets need to travel from their bivouac to the material reserve area to load the corresponding disaster relief materials, then unload them at the disaster site according to the designed route plan and return to the bivouac. Therefore, in the DNA sequence, the transport routes for the first fleet are 10-0-3-2-10, for the second fleet are 10-0-1-6-5-10, for the third fleet are 10-0-4-9-0, and for the fourth fleet are 10-0-8-7-0. The genetic process in the population is based on genetic variation and natural selection. In the initial stage, it is generated based on random sequences, exhibiting complexity and diversity. As the population size increases, the diversity also increases. The more high-quality individuals in the initial population, the more offspring there will be after crossing and mutation. Consequently, the computation grows geometrically, necessitating the setting of population size for efficient computation.

(2) Crossover operator and mutation operator. By dividing the initial population into pairs, then using the crossover  $p_c$  operator to calculate a random number  $p_t$ ; when  $p_t$  is less than  $p_c$ , a crossover operation will occur, thus generating new individuals. In the process of crossover operation, two design schemes are adopted. The first operation is based on the partially matching crossover (PMX) method, and the second is a gene exchange analysis by crossing, moving them to the beginning, and removing duplicate items to produce two different offspring. There are two common types of crossover:

The first type of crossover:

$$\begin{cases} A1 = (12|345|67) \\ B1 = (13|576|42) \end{cases} \rightarrow \begin{cases} A4 = (12|576|34) \\ B4 = (17|345|62) \end{cases}$$

The second type of crossover:

$$\begin{cases} A1 = (12|345|67) \\ B1 = (13|576|42) \end{cases} \rightarrow \begin{cases} A2 = ([576]1234567) \\ B2 = ([345]1357642) \end{cases} \rightarrow \begin{cases} A3 = ([576]1234) \\ A4 = ([345]1762) \end{cases}$$

During the specific mutation operation, firstly, the individuals within the entire population are analyzed, and when  $p_t$  is less than  $p_c$ , new individuals are generated by performing corresponding mutations on the respective individuals. The specific mutation logic is to reverse the segments of the disaster point sequence in the chromosome,

mutate random items in the gene sequence into other numbers, and then reorder them to obtain the DNA sequence of the individual.

$$\begin{cases} DNA_1 = (32|1654|987) \\ DNA_2 = (2|5|7) \end{cases} \rightarrow \begin{cases} DNA_1 = (32|4561|987) \\ DNA_2 = (27|8) \end{cases}$$

The offspring population obtained after the crossover and mutation operator operations is treated as the new population, and its quantity should be  $(1 + p_m + p_c)$  times that of the original population. In the specific crossover operation process, it is to exchange excellent DNA to obtain high-quality offspring, and mutation operation is to enhance the diversity of the population and avoid local optima.

(3) Feasibility. In the process of the above model constraints, the main constraint is the fleet load capacity, based on which the new population constraint conditions are judged to achieve uniform feasibility. The specific feasibility is carried out according to the following ideas: first, analyze the paths of infeasible solutions, analyze the overloaded fleets  $k_{max}$  and the fleets  $k_{min}$  with the least load, and then transfer the demand points from the overloaded fleets to the paths of the fleets with the least load. If the load constraint still cannot be satisfied after looping through this process seven times, the individual will be deleted. Test results show that if inferior individuals are not processed for feasibility, the number of inferior individuals to be deleted from the initial population exceeds 50%. After processing with the feasibility algorithm, the number of deletions per iteration is 0.57 after 5000 iterations.

(4) Natural selection. After performing the feasibility processing, fitness is calculated, and excellent populations are selected for the next generation calculation. The total population size is set to be the same as the size of the initial population. To ensure the clear difference between high-quality and inferior individuals in the selection process, the specific calculation function is as follows:

$$f = \frac{1}{(\min Z)^2} \quad (8)$$

(5) Termination criteria. End the iteration loop when the number of iterations reaches the maximum set value.

## 4. Example Analysis

Assuming an earthquake disaster occurs in a certain region, an analysis is conducted based on the data of the first 15 and last 15 locations in the area. Ensuring the demand points at different locations, the coordinates of the material reserve position are [62,78], and the coordinates of the troop stationing position are [49,31]. The load capacity of a single vehicle is  $Q=6$ , each convoy consists of 7 vehicles, totaling 8 convoys, with a loading and unloading time of 0.5 each, and a vehicle traveling speed of 40. Material demand  $G_i$  and the latest arrival time  $LT_i$  are shown in Table 1.

**Table 1.** Information on material requirements and latest arrival times at disaster sites

i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
G <sub>i</sub>	5	11.3	10.3	13.5	10.6	8.3	9.8	11.7	8.6	8.2	17.2	13.5	8	9.4	6.2
Lt <sub>i</sub>	4.5	2.8	3.8	6.8	3.5	4.7	2.9	4.5	7.1	3.5	5.8	4.3	3.2	2.5	4.1
i	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
G <sub>i</sub>	11.23	14.3	8.3	11.1	4.5	5.8	6.7	8.4	7.6	2.5	14.3	12.5	6.8	7.3	10.3
Lt <sub>i</sub>	3.04	2.71	2.58	5.48	3.28	5.81	2.84	5.73	3.32	2.49	4.88	4.56	2.16	2.88	5.75

Combining the data of this region with the above improved genetic algorithm for testing and analysis, with a crossover probability of  $P_c = 0.8$ , a mutation probability of  $P_m = 0.1$ , and penalty coefficients  $\alpha=40$ ,  $\beta=100$ , a

population size of 80, and a maximum iteration of 5000 times, optimization solutions were conducted 10 times, with test results shown in Table 2, and optimal path diagrams and iterative processes shown in Figure 1 and Figure 2.

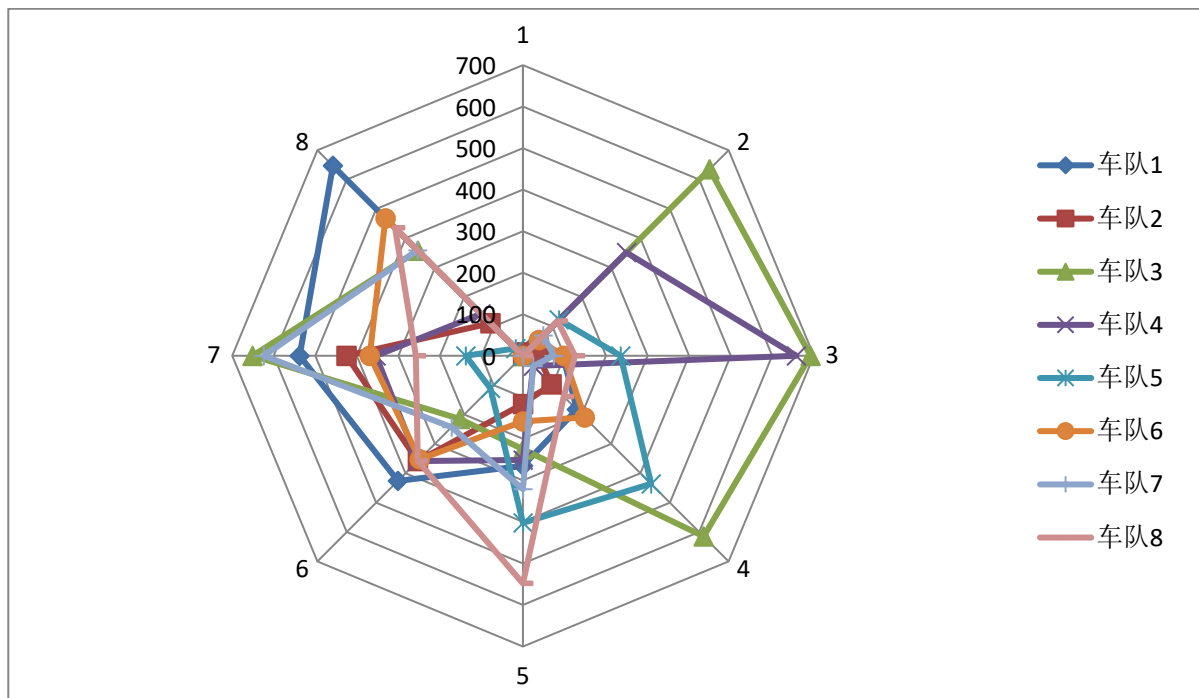
**Table 2.** Test Results

Num.	Objective function Z	Total distance S	Number of iterations	Computation time
1	5248.75	749.82	4276	84
2	4979.85	711.41	3671	85
3	5116.14	730.88	2286	85
4	5012.40	716.06	4670	76
5	4947.90	706.84	3723	78
6	5121.03	731.58	1373	85
7	4908.47	701.21	1733	86
8	5131.13	733.02	1890	90
9	4902.78	700.40	4639	84
10	5125.58	732.23	2220	84
Average value	5049.40	721.35	3048	84

The calculation results are as follows:

The travel distance of the first convoy is 97.32km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 4.87 hours, and a convoy loading rate of 96%; the travel distance of the second convoy is 103.57km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 5.64 hours, and a convoy loading rate of 68%, where the convoy can reduce one transport vehicle; the travel distance of the third convoy is

89.32km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 4.63 hours, and a convoy loading rate of 84%; the travel distance of the fourth convoy is 57.63km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 3.62 hours, and a convoy loading rate of 53%, where the convoy can reduce two transport vehicles; the travel distance of the fifth convoy is 87.21km, with a total time consumption



**Figure 1.** Graphical representation of the optimal path

from accepting the task from the transportation department to completing the entire task of 5.01 hours, and a convoy loading rate of 94%; the travel distance of the sixth convoy is 63.51km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 3.03 hours, and a convoy loading rate of 81%, where the convoy can reduce one transport vehicle; the travel distance of the seventh convoy is 68.32km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 3.62 hours, and a convoy loading rate of 73%, where the convoy can reduce one transport vehicle; the travel distance of the eighth convoy is 94.58km, with a total time consumption from accepting the task from the transportation department to completing the entire task of 5.43 hours, and a convoy loading rate of 90%.

According to this vehicle scheduling plan, 8 convoys with 50 transport vehicles can complete the emergency transportation task.

From the 10 test results, we can know each optimal solution falls within the rescue time window demand range, meeting the actual needs of relief material vehicle transportation time and the material demand at disaster points. Additionally, it can provide optimal paths for different vehicle scheduling problems, ensuring the completion of transportation requirements in the shortest time possible and enhancing the efficiency of emergency transportation. The improved genetic algorithm demonstrates good convergence in solving optimization problems in military disaster relief material transportation vehicle scheduling systems.

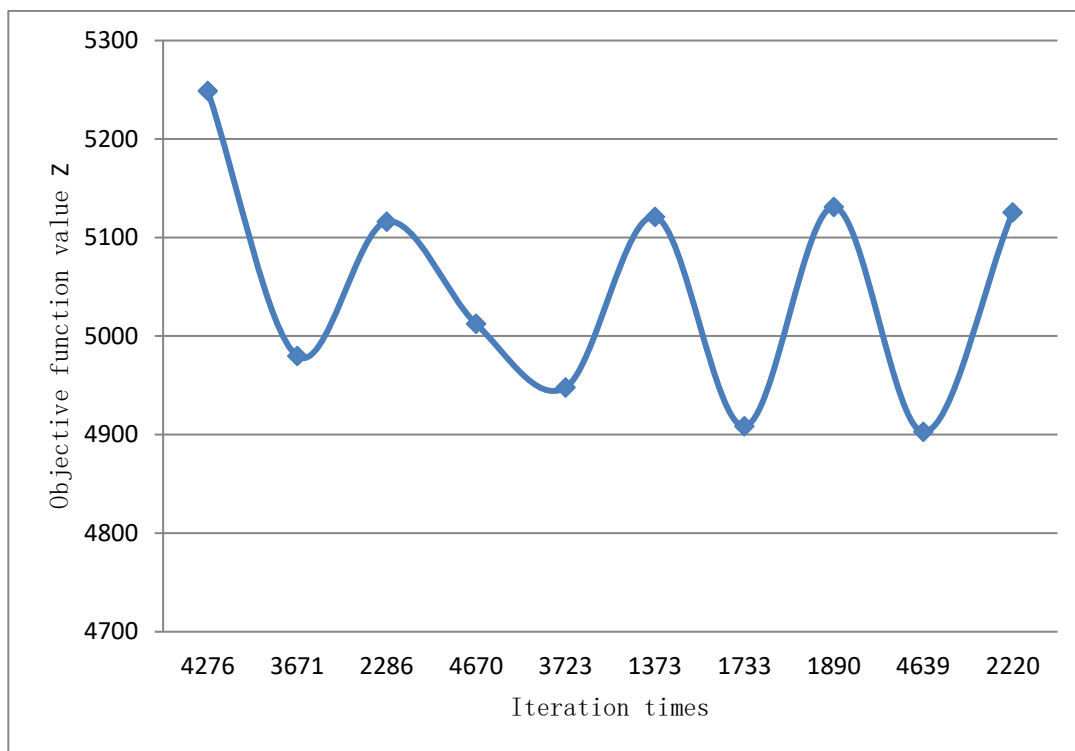


Figure 2. Iterative process

## 5. Conclusion

Emergency transportation plays a crucial role in the process of emergency management, whether it's in common disaster relief efforts or public event handling, efficient transport of emergency supplies is essential. To enhance the effectiveness of military transportation tasks in facing natural disasters, this article constructs a relief supplies transportation vehicle scheduling model based on time efficiency. The objective function is to minimize the total distance with a time penalty function, and an improved genetic algorithm is used for optimization. The main methods include using PMX operators and similar PMX operators for crossover, and a combination of reverse mutation of disaster-affected point sequences and single-point mutation of breakpoint sequences for mutation. The research results indicate that the improved genetic algorithm can effectively address the problem of premature convergence, so as to achieve more efficient and accurate vehicle scheduling schemes, play out the advantages of the army organization, and provide reference for the army

to achieve emergency transport scheduling decisions.

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