Research on Multi Maintenance Stations Scheduling Method for Passenger Elevators with Considering Priority

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Abstract—Aiming at the problem that the current passenger elevator maintenance scheduling mainly relies on manual work and cannot meet the large-scale maintenance scheduling which needs to consider the priority, a multi-optimization objective and multi-maintenance station maintenance scheduling method considering the priority of maintenance tasks was proposed. Firstly, the maintenance scheduling characteristics of multiple maintenance stations were analyzed, and the task of multi-maintenance station scheduling was decomposed into a single maintenance station maintenance scheduling model using K-means ++ algorithm. Then, an improved NSGA-II algorithm for single maintenance station scheduling was proposed to consider the priority of maintenance tasks, and a double-strand coding method was designed. At the same time, the crossover operator and mutation operator are improved, and finally the case analysis is carried out. The analysis results show that the proposed method can quickly realize multi-station maintenance scheduling considering priority, and the number of maintenance personnel required by different maintenance stations is different. The proposed method can provide reference for the formulation of maintenance route and the determination of maintenance personnel.

Keywords-component; Priority; Maintenance scheduling; NSGA-II; Multiple maintenance stations

1. Introduction

The number of elevators in China has reached more than 8.79 million till the end of 2021. With the continuous increase of elevators, there are frequent failures such as trapped people, overspeed and emergency braking in elevator operation, and the safety situation of elevators is not optimistic. Among the factors leading to potential elevator safety risks, the maintenance and use of elevators take up to 60%. In order to improve the level of elevator safety, China began to carry out on-demand maintenance, advocating real-time monitoring of elevator status, warning and elimination of elevator safety hazards. The on-demand maintenance mode enables maintenance personnel to refer to the preferred maintenance route to carry out on-site maintenance of abnormal elevator equipment in turn and eliminate potential safety risks. Traditional elevator maintenance is based on the maintenance of the elevator maintenance personnel to arrange their own maintenance route, this decision-making mode relies heavily on the scheduling experience of maintenance personnel, often can not get the best maintenance route. Under the on-demand maintenance mode, the service area of elevator maintenance dispatching cloud platform expands, the maintenance tasks are more complex and diversified, and the number of maintenance stations and maintenance personnel involved is more. The traditional manual scheduling method cannot support the optimization of large-scale maintenance scheduling, so it is urgent to propose a scientific and efficient maintenance scheduling decision-making method.

Maintenance scheduling problem involves three elements: maintenance station, maintenance personnel and maintenance task. Maintenance station can be abstracted into depot, maintenance personnel into vehicles and maintenance task into customers. Maintenance scheduling problem of elevator multi-maintenance station can be regarded as a special multi depot vehicle routing problem (MDVRP). MDVRP is introduced by Gillett [1] on the basis of VRP problem. In route planning, vehicles of each depot can participate in scheduling. According to different constraints, the MDVRP problem also has different subdivisions, such as open parking constraints [2], customer service time constraints [3], multi-optimization objectives [4][5], etc.

Compared with single-depot VRP problem, MDVRP problem needs to consider more factors and is more difficult to solve. According to different solving ideas, MDVRP problem solving methods can be divided into the following two categories: global method and decomposition method. The global method is to establish the mathematical model of MDVRP problem as a whole for solving. It takes the problem into consideration more comprehensively, and the results obtained are of higher quality. However, there are also some shortcomings, such as the mathematical model established is more complex and the solving cost is higher.

Decomposition method divides a complex problem into several sub-problems in an appropriate way. For example, customer clustering method [6] is adopted to find the solutions of each sub-problem respectively. When solving the MDVRP problem, the task is first assigned with the depot as the unit, and the completed set of customers and the depot can be regarded as an independent VRP problem of the single depot. Then, the optimal path of the VRP problem of the single depot is obtained respectively, and the solutions of each VRP problem obtained together form the satisfactory solution of the

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DOI 10.1109/ISSSR58837.2023.00039

whole MDVRP problem [7]. The core of decomposition method is depot allocation. Common methods include customer clustering. In conclusion, the global approach is more reasonable in task allocation and can maximize the optimization of maintenance resources. However, as the scale of the problem increases, the efficiency of solving the problem decreases significantly. Decomposition method has more advantages in dealing with large-scale problems, but its difficulty lies in how to allocate the tasks of each warehouse reasonably in parallel optimization and improve the quality of the comprehensive solution.

In order to meet the realistic demand of large-scale maintenance resource scheduling optimization under the mode of on-demand maintenance, the task allocation and single maintenance station maintenance scheduling optimization were studied. Firstly, for the multi-maintenance station scheduling problem considering priority, the decomposition method and K-means ++ clustering algorithm were used to allocate maintenance tasks to the corresponding maintenance stations. On this basis, the maintenance scheduling model of single maintenance station was established, which took the minimum total maintenance travel and the minimum total personnel involved in maintenance tasks as the optimization objective, and an improved genetic algorithm based on double-strand coding was proposed. Finally, the validity of the model and algorithm is verified

2. Construction of Maintenance Scheduling Model

Elevator maintenance scheduling needs to consider multiple maintenance stations, multiple optimization objectives, task priority and other factors. The maintenance scheduling problem can be described as: a maintenance company has multiple repair stations, each of which can provide repair services for elevator equipment, with a sufficient number of repairmen and the same quality of service. Maintenance tasks of different types have different maintenance duration and priorities. Maintenance tasks with high priority must be completed in advance. Each maintenance person is responsible for only one of the highest priority maintenance tasks. Starting from the maintenance station, the maintenance personnel provide maintenance services for the equipment to be maintained in turn. After completing the planned maintenance task, the maintenance personnel should return to the original maintenance station. Considering the locations of maintenance stations and maintenance tasks, the service time and priority of maintenance tasks, as well as the conversion speed of maintenance personnel, a maintenance scheduling scheme satisfying the optimization objectives was solved on the premise of meeting the priority requirements of maintenance routes. The optimization objective is to minimize the total maintenance distance and the total number of maintenance personnel participating in maintenance tasks.

As the problem of multi-station maintenance scheduling is a typical NP problem, it is very difficult to solve directly. The decomposition method is considered to transform the problem of multi-station maintenance scheduling into several single-station maintenance scheduling problems. The specific form of multi-maintenance station maintenance scheduling is shown in Fig 1, and the priority of tasks is represented by numbers 1, 2, and 3, where: 1 represents the highest priority, followed by 2, and so on. There are three maintenance stations in the figure, two kinds of priority maintenance tasks, and several maintenance routes in each maintenance station. Maintenance personnel start from the maintenance station, pass through the maintenance task point successively, and finally return to the original maintenance station. In each maintenance route, the high priority task is executed earlier, and there is only one maintenance task with priority 1.

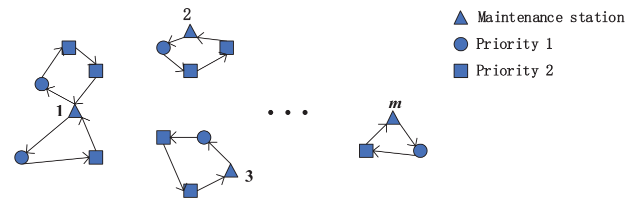


Figure 1. Schematic diagram of multi-station maintenance scheduling

3. Two - Stage Solution of Maintenance Scheduling Model

3.1. Multi-maintenance station scheduling task decomposition based on K-Means++

When solving such problems, the global optimization algorithm has problems such as high difficulty and low speed [8]. In order to reduce the difficulty and improve the computational efficiency, the decomposition method is used to convert the maintenance scheduling problems of multiple maintenance stations into several single maintenance station maintenance scheduling problems, and then the maintenance scheduling problems of single maintenance station are solved respectively. It can be divided into task allocation and maintenance scheduling optimization. In the first stage, K-means ++ was adopted to decompose the multi-maintenance station scheduling problem into multiple single-maintenance station scheduling problems. In the second stage, NSGA-II was adopted to solve the single-maintenance station scheduling problem. The specific solution route is shown in Fig 2.

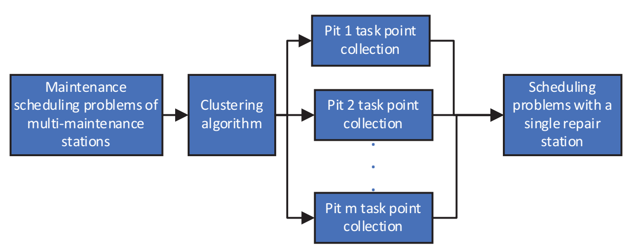


Figure 2. Multi-station maintenance scheduling solution roadmap

3.2. Maintenance scheduling of single maintenance station based on improved NSGA-II

3.2.1. Construction of single maintenance station maintenance scheduling model

- Basic assumption

The maintenance scheduling problem of a single maintenance station involves many aspects, such as the number of maintenance personnel, service time and priority of maintenance tasks, and transfer speed of maintenance personnel. In order to further establish the mathematical model, the following assumptions are made in this paper:

① The number of maintenance personnel in the maintenance station is sufficient, with the ability to handle various types of maintenance tasks, and the maintenance level is the same;

② The maintenance personnel start from the maintenance station and return to the original maintenance station after completing all tasks;

③ The distance between the maintenance station and the maintenance task and the distance between the maintenance task are Euclidean distance

④ Each maintenance personnel can handle multiple maintenance tasks, but each maintenance task is only undertaken by one maintenance personnel;

⑤ When handling maintenance tasks, maintenance personnel need different maintenance time according to different types of maintenance tasks;

⑥ There is only one maintenance route for each maintenance personnel. The maintenance tasks with higher priority need to be repaired earlier. Maintenance personnel transfer speed is uniform, and the planned working time shall not exceed the rated working time.

- Parameter setting and model construction

m : The number of maintenance personnel actually involved in maintenance

n : Number of maintenance tasks.

C : The number of priority maintenance tasks.

T_j : Service time required for the j-maintenance task, $j \in (1,2,\cdots,n)$.

T_e : Rated working hours of maintenance personnel.

V_e : Transfer speed of maintenance personnel.

D_{ij} : Euclidean distance between two points. $i \in (0,1,2,\cdots,n)$, $j \in (0,1,2,\cdots,n)$, when $i = j$, $D_{ij} = 0$;

R_{ij} : Priority comparison results between maintenance stations and each maintenance tasks, $i \in (0,1,2,\cdots,n)$, $j \in (0,1,2,\cdots,n)$, the maintenance station has the lowest priority. If the priority of task i is higher than or equal to the priority of task j . $R_{ij} = 1$;else , $R_{ij} = 0$.

x_{ijk} : In the maintenance route of maintainer k , is there a direct transfer between each maintenance station and each maintenance task point, $i \in (0,1,2,\cdots,n)$, $j \in (0,1,2,\cdots,n)$,If there is $x_{ijk} = 1$,else $x_{ijk} = 0$

y_{jk} : Check whether maintenance task j exists in the maintenance path of maintainer K , $j \in (0,1,2,\cdots,n)$, If there is $y_{jk} = 1$,else $y_{jk} = 0$

z_{ck} : Number of maintenance tasks whose priority is C in the maintenance route of maintainer K , $c \in (1,2,\cdots,C)$

By analyzing the working mode of maintenance personnel, it can be seen that the working time of maintenance personnel consists of maintenance service time and transfer time. The transfer time of maintenance personnel is an important part of the work time. The maintenance scheduling algorithm is used to optimize maintenance routes to minimize the transfer time of maintenance personnel and improve the utilization efficiency of maintenance resources. Maintenance personnel transfer time T_s is related to the optimized maintenance route, which is expressed as follows:

$$T_s = \sum_{i=0}^{n}\sum_{j=0}^{n}\left(\frac{D_{ij}}{V_e} \times x_{ijk}\right), k \in (1,2,\cdots,m) \tag{1}$$

Since the maintenance level of maintainers is the same, the maintenance service time is mainly determined by the type of maintenance tasks, and different maintenance types correspond to different maintenance service times. Therefore, when the maintenance route of maintainers is determined, the maintenance service time T_m can also be obtained as follows:

$$T_m = \sum_{j=1}^{n}(T_j \times y_{jk}), k \in (1,2,\cdots,m) \tag{2}$$

The objective function of the shortest total maintenance trip and the least number of maintenance personnel participating in maintenance tasks is:

$$\min f_1 = \sum_{k=1}^{m}\sum_{i=0}^{n}\sum_{j=0}^{n}(D_{ij} \times x_{ijk}) \tag{3}$$

$$\min f_2 = k \tag{4}$$

$$\text{s.t. } \sum_{i=0}^{n}\sum_{j=0}^{n}\left(\frac{D_{ij}}{V_e} \times x_{ijk}\right) + \sum_{j=1}^{n}(T_j \times y_{jk}) \le T_e, k \in (1,2,\cdots,m) \tag{5}$$

$$R_{ij} > 0 \tag{6}$$

$$\sum_{i=0}^{n} x_{ijk} = y_{jk}, k \in (1,2,\cdots m), j \in (1,2,\cdots n) \tag{7}$$

$$\sum_{j=1}^{n} x_{ijk} = y_{ik}, k \in (1,2,\cdots m), \mathrm{i} \in (0,1,\cdots n) \tag{8}$$

$$\sum_{i=0}^{n} x_{i0k} = 1, k \in (1, 2, \cdots, m) \tag{9}$$

$$\sum_{k=1}^{m} y_{jk} = 1, j \in (1, \cdots n) \tag{10}$$

$$z_{1k} \leq 1, k \in (1, 2, \cdots, m) \tag{11}$$

Where, (5) indicates that the planned working hours of maintenance personnel do not exceed the rated working hours; (6) represents the priority constraint of maintenance tasks in the maintenance route. High priority maintenance tasks need to be completed earlier; (7), (8) represents the balance constraint of vehicles entering and leaving the task point; (9) indicates that the maintenance personnel need to return to the maintenance station after completing the assigned maintenance tasks; (10) indicates that a maintenance task can only be serviced by one maintenance personnel; (11) indicates that each maintenance route can have at most one maintenance task with priority 1.

3.2.2. Solving NSGA-II algorithm considering priority

The traditional genetic algorithm is difficult to weigh the pros and cons of multiple objectives when solving multi-objective optimization problems, so the final output solution is not satisfactory. NSGA-II, proposed by Deb et al [9], has a good effect on dealing with multi-objective optimization problems. Compared with NSGA algorithm, the former algorithm optimizes NSGA in terms of algorithm efficiency and population diversity. The flowchart of NSGA-II is shown in Fig 3.

The maintenance scheduling problem of single maintenance station considers the priority of the task, which cannot be reflected by traditional coding method [10]. Therefore, in this paper, on the basis of the double-strand coding method to improve the traditional coding method to meet the requirements of solving this problem. On this basis, the existing genetic operators are improved to meet the new solving requirements. The main contents are as follows:

- Coding

  Coding is to map the solution space of the problem to the search space that can be processed by genetic algorithm [14]. Common coding methods include binary coding and natural number coding, etc. However, these coding methods have great limitations in solving the maintenance scheduling problem of single maintenance station, and the generated chromosomes cannot directly represent the priority information of maintenance tasks. Therefore, a double-strand coding method is adopted in this paper to represent the feasible solution of the problem by using two linear linked lists of equal length, in which the first linked list represents the serial number of the maintenance task, and the second linked list represents the serial number of the maintenance personnel responsible for the corresponding maintenance task. Its structure is shown in Fig 4. The corresponding task of each maintainer is its maintenance path. Fig 4 is used as an example. The maintenance paths of maintainer A1 are T0-T2-T4-T9-T0.

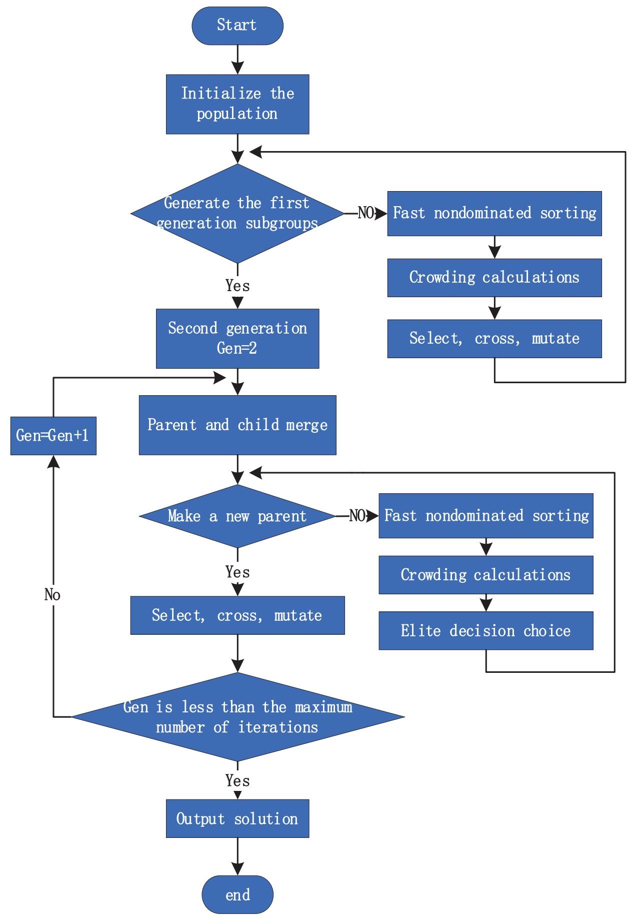


Figure 3. Flow chart of the NSGA – II

Task	T2	T1	T5	T3	T4	T6	T8	T7	T9	T10
Maintenance officer	A1	A3	A2	A2	A1	A3	A2	A2	A1	A3

Figure 4. Double-strand coding

- Initial population

  Initial population is the basis for genetic algorithm to search feasible solutions, and a reasonable initial population is conducive to improving the operation efficiency of the algorithm. In order to describe the generating process of initial population, the following definitions are made:

  L : The number of priorities in the task set;

  P_i : The i-th priority task set, $i \in (1, 2, \cdots, L)$;

  S_i : The i-th priority task set that has not completed the assignment, $i \in (1, 2, \cdots, L)$;

  N : population quantity.

  When generating the initial population, in order to meet the priority requirements of individuals, the task allocation process is divided into several stages according to the priority order of the task set. Then, in each stage, maintenance personnel are randomly assigned to each task with the same priority in the task set. Finally, the feasibility verification of the generated individuals is carried out until a certain number of individuals are generated.

①$k=1$。

②$T=\varnothing, A=\varnothing, i=1, S_i=P_i$

③If $S_i=\varnothing$,go to ④; else, from the task set of S_i , select S_i task at random and assign S_i maintainer to it. In particular, when $i=1$,the assigned maintainer does not participate in the current task assignment. The paired gene is added to the chromosome tail, and the currently selected task is deleted from S_i ,go to ③.

④$i=i+1, if\ \ i\le L, S_i=P_i$ go to ③, else go to ⑤.

⑤If the total working time of a maintainer exceeds the rated working time, go to ②; else $k=k+1$

⑥If $K\le N$,go to ②; else output an initial population with N chromosomes.

- Crossover operator
  Crossover operator is used to exchange gene fragments of two parent chromosomes to generate two new chromosomes. Its performance directly affects the evolution speed and solving quality of the population. Partially-matched crossover (PMX) is adopted in this paper, and the schematic diagram is shown in Fig 5.

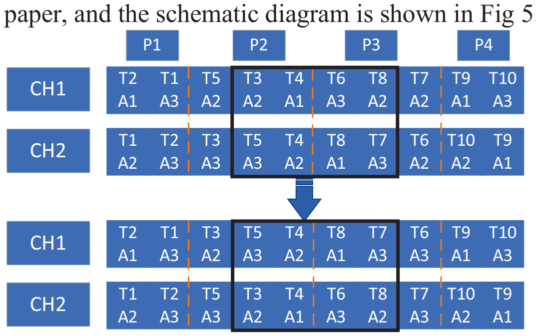


Figure 5. PMX crossover operator

- Mutation operator
  Considering the particularity of chromosome structure encoded by double-strand, in order to improve the degree of chromosome variation, this paper designed two variants, random variation and swap variation.

(1) Random variation

Randomly select a gene locus and mutate its corresponding maintainer into other maintainers, as shown in Fig 6. In particular, considering that the highest priority task is usually urgent, each maintainer can only be responsible for one task with priority 1. Therefore, if the task priority of the selected mutant gene is 1, it is also necessary to ensure that the mutant safeguard unit cannot be responsible for other tasks with priority 1.

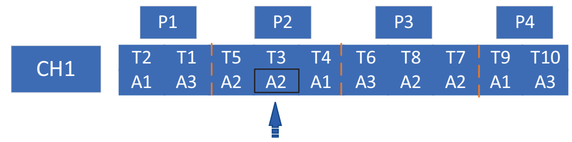


Figure 6. Schematic diagram of random variation

(2) Commutative variation

First, a priority is randomly selected from the parent chromosome, and the number of tasks of this priority is not less than 2. Then two positions are randomly identified in the gene segment corresponding to that priority, and their genes are exchanged to get a new chromosome. Details are shown in Fig 7.

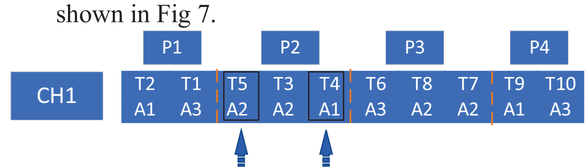


Figure 7. swap mutation schematic diagram

- Compromise optimal solution
  Multi-objective optimization results in a series of solutions, and the decision maker selects the desired solution. In order to facilitate decision makers to choose, fuzzy theory is introduced to select the compromise optimal solution from a series of solutions [11]. The satisfaction of each pareto optimal solution in a one-dimensional objective function is shown in (12), and the satisfaction of each pareto optimal solution is shown in (13). In the formula, f_i^m is the m-dimensional objective function value of the optimal solution $i,m\in\{1,2,\cdots,N_{obj}\}$ $f^{m,\min}$, $f^{m,\max}$ are the minimum and maximum values of the m-dimensional objective function value respectively. N_c is the number of optimal solutions. The Pareto optimal solution with the greatest satisfaction is selected as the compromise optimal solution.

$$\mu_i^m\begin{cases}1, & f_i^m\le f^{m,\min}\\ \dfrac{f^{m,\max}-f_i^m}{f^{m,\max}-f^{m,\min}}, & f^{m,\min}<f_i^m<f^{m,\max}\\ 0, & f_i^m\ge f^{m,\max}\end{cases} \tag{12}$$

$$\mu_i=\frac{\sum_{m=1}^{N_{obj}}\mu_i^m}{\sum_{i=1}^{N_c}\sum_{m=1}^{N_{obj}}\mu_i^m} \tag{13}$$

4. CASE ANALYSIS

This section takes the maintenance task data of an elevator maintenance company at a certain time as an example to analyze the effectiveness of the text maintenance scheduling algorithm. The company has three repair sites in the region with a total of 40 repair tasks. It is assumed that maintenance personnel have the same level of maintenance skills and are competent for various types of maintenance tasks, with an average turnover speed of 40 km/h and a fixed working time of 8h for maintenance personnel. See Table 1 for maintenance task information and Table 2 for specific maintenance site information.

Table 1． Maintenance task table

Serial number	longitude	latitude	Task priority	Task time	Serial number	longitude	latitude	Task priority	Task time
1	120.2391788	30.19355355	1	60	21	120.263024	30.24155407	2	30
2	120.1856029	30.18374009	1	30	22	120.488811	30.26255008	3	20
3	120.1739978	30.33328579	3	20	23	120.2704706	30.18751122	3	20
4	120.1564988	30.354216	3	20	24	120.0307152	30.29566085	3	20
5	120.214827	30.35776597	1	30	25	120.0268654	30.27758216	3	20
6	120.2722006	30.33545181	2	30	26	120.0440061	30.25132021	1	30
7	120.2045077	30.26710155	3	20	27	120.131382	30.38177895	3	20
8	120.256631	30.32613498	3	20	28	119.8621931	30.34395568	1	90
9	120.32064	30.30740004	3	20	29	119.8949265	30.25490678	2	30
10	120.2123393	30.23691349	3	20	30	119.9716255	30.27648034	3	20
11	120.2042899	30.23261819	3	20	31	119.990898	30.28499102	2	30
12	120.1529702	30.26997373	2	30	32	120.0682813	30.36252098	1	60
13	120.106233	30.17294012	2	30	33	120.0911839	30.35917475	3	20
14	120.1472658	30.28118717	1	30	34	120.2797185	30.46047556	2	30
15	120.1850723	30.32932596	3	20	35	120.0811073	30.4490879	3	20
16	120.1877288	30.28684891	2	30	36	119.959604	30.25130204	2	30
17	120.2583793	30.12284467	2	30	37	119.9880823	30.25018729	2	30
18	120.2907352	30.24923335	2	30	38	119.9490256	30.26265886	3	20
19	120.388376	30.24831107	1	90	39	119.910663	30.26792002	3	20
20	120.2749356	30.17675397	3	20	40	119.952044	30.28284804	3	20

Table 2. Details of maintenance site

Serial number	longitude	latitude
1	120.2648	30.220216
2	119.96505	30.274984
3	120.171347	30.349087

In order to arrange the maintenance route reasonably, the multi-maintenance station maintenance scheduling algorithm is adopted. Firstly, the clustering algorithm is used to assign maintenance tasks to each maintenance station, and the analysis results are shown in Table 3.

Table 3. Maintenance task classification table

Maintenance site	Assigned task
1	1,2,6,7,8,9,10,11,17,18,19,20,21,22,23
2	13,24,25,26,28,29,30,31,36,37,38,39,40
3	3,4,5,12,14,15,16,27,32,33,34,35

As can be seen from Table 3, the clustered maintenance tasks are assigned to each maintenance station, and then the improved genetic algorithm can be used for each maintenance station to solve the optimal path satisfying the task priority, in which the actual distance between each maintenance task point is converted from the longitude and latitude coordinates.

The population size is set to 30, the crossover probability is 0.7, the mutation probability is 0.3, and the evolutionary algebra is 500. The maintenance roadmap and Pareto results of each maintenance station are shown in Fig9-Fig11. Compared with the GA using double-strand coding, the evolutionary algebra is 500. The optimized maintenance routes of each maintenance station are shown in Table 4, and the evolution comparison of the two algorithms is shown in Figure 12-13.

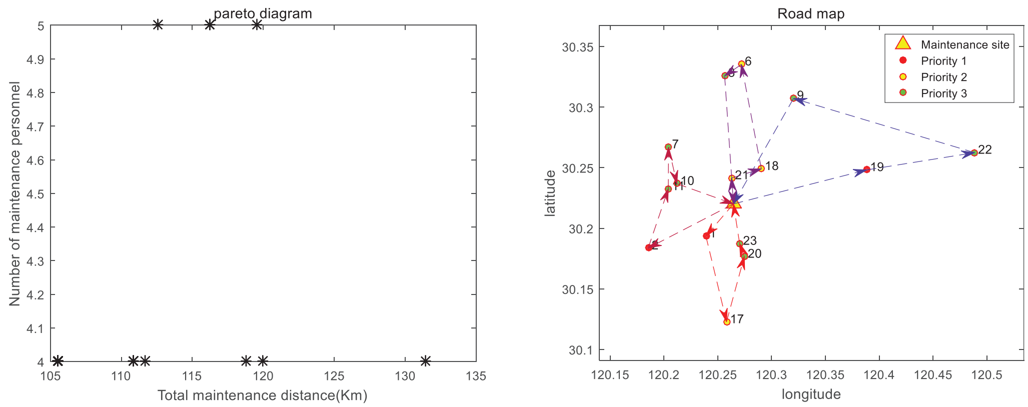
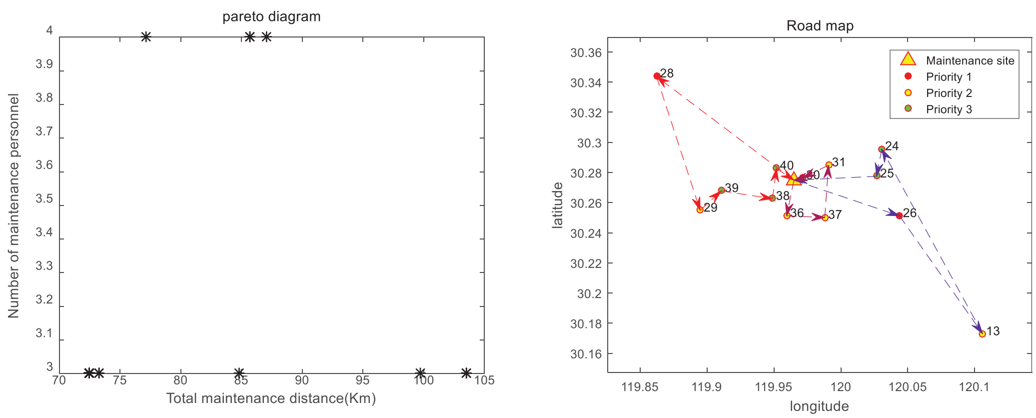
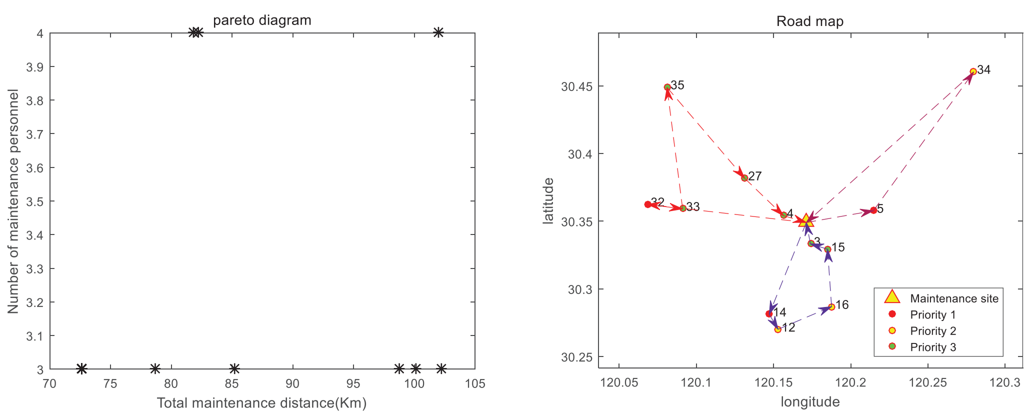


Figure 9. (a)Maintenance station 1 pareto chart,(b) Roadmap of the optimal compromise solution for maintenance station 1



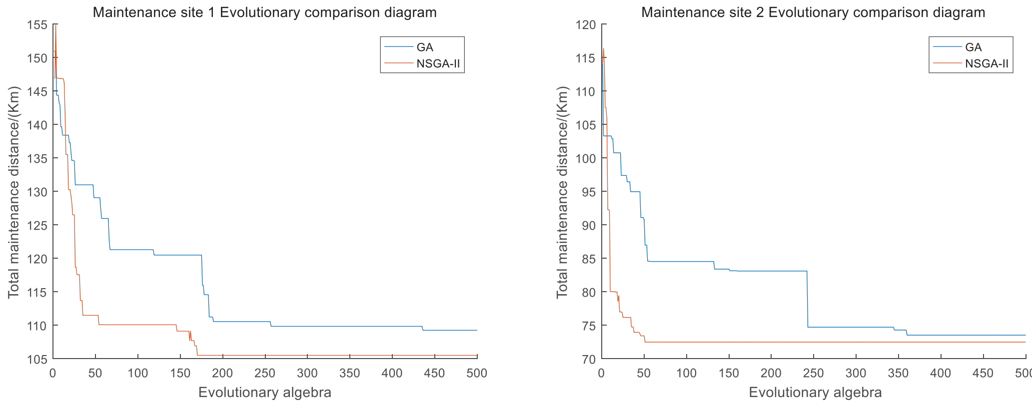
(a) (b)

Figure 10. (a)Maintenance station 2 pareto chart,(b) Roadmap of the optimal compromise solution for maintenance station 2



(a) (b)

Figure 11. (a)Maintenance station 3 pareto chart,(b) Roadmap of the optimal compromise solution for maintenance station 3



(a) (b)

Figure 12. (a)Evolution comparison of maintenance Site 1,(b)Evolution comparison of maintenance Site 2

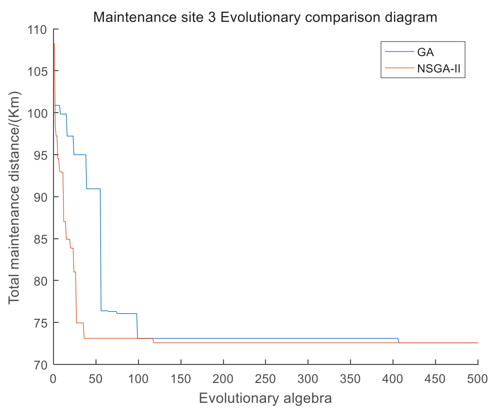


Figure 13. Evolution comparison of maintenance Site 3

The final results of the scheme show that a total of 10 maintenance personnel participate in the scheduling, and the total maintenance path is 250.28Km. As can be seen from the figure above, the optimized maintenance routes of each maintenance station meet the priority requirements. High-priority tasks are processed before low-priority tasks, and only one task with priority 1 exists. Both GA and NSGA-II meet the requirements. After optimization, the number of maintenance personnel required for different sites and the total maintenance trips are different. To provide the basis for the number of station maintenance personnel. Further observation of Figure 12-13 shows that the convergence rate of NSGA-II algorithm using double-strand coding is significantly faster than that of GA algorithm, and after 500 generations of evolution, the total maintenance distance of the first and second maintenance stations is less than that of GA. The superiority of double-strand coding NSGA-II algorithm is proved. In the traditional maintenance mode, one maintenance person can be responsible for the maintenance work of 50 elevators at most, and the average needs to maintain 2 to 3 elevators every day. In this example, at least 14 maintenance personnel are required to solve the problem using traditional maintenance methods, while the solution in this paper requires only 10 maintenance personnel, which represents a savings of 28%. It can be seen that the scheme in this paper can effectively save human resources on the basis of ensuring the minimum maintenance distance.

Conclusion

Aiming at the maintenance scheduling problem of multiple maintenance stations considering priority, this paper designed an improved genetic algorithm of double-strand considering priority. Taking the shortest total maintenance trip and the least number of total maintenance personnel as optimization objectives, the maintenance task was divided into a single maintenance station task scheduling by using K-mean ++, and the maintenance scheduling of a single maintenance station was optimized.

(1) Using K-means ++ to realize the decomposition of multi-maintenance station maintenance scheduling requirements;
(2) Double-strand coding mode was introduced into NSGA-II to avoid adding task priority comparison into constraint conditions, and maintenance scheduling considering task priority was realized with the minimum total maintenance travel and minimum number of total maintenance personnel as optimization objectives.
(3) The improved NSGA-II is applied to realize the optimization of multi-station maintenance route, which shows the effectiveness of the algorithm. The analysis results show that the number of maintenance personnel in each maintenance station is different, and the number of equipment maintained by each maintenance personnel is also different, which also provides a reference for the personnel configuration of the maintenance station.
(4) Compared with GA, the double-strand NSGA-II solution has higher quality and faster convergence rate. Compared with the traditional maintenance method, the algorithm saves 28% of human resources.

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