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"TIME-CRITICAL TRANSPORT: RESEARCHING IMPROVED GENETIC ALGORITHMS FOR SCHEDULING METRO CONSTRUCTION MUCK VEHICLES DURING RESTRICTED HOURS

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Abstract
For the time scheduling problem of each station's muck transportation vehicle and muck processing center during the construction of the under-construction subway station, a muck transportation time scheduling optimization model with the shortest vehicle waiting time and processing plant waiting time as the objective function is established, and the genetic algorithm is improved by repairing the chromosomes of the individuals who violate the constraints and introducing the elite strategy. The effectiveness of the model and algorithm is verified by examples. The results show that the proposed model can efficiently perform unified scheduling for the transportation of spoil at multiple construction sites, and the designed algorithm has good merit-seeking capability.

Keywords: Vehicle Routing Problem; Improved Genetic Algorithm; Cooperative Scheduling

1. Introduction

In recent years, China's urban rail transit construction has developed rapidly, and in 2021 China's urban rail transit operating mileage is 8708 km, an increase of 2.4 times compared to 3618 km in 2015. Among them, the subway operating mileage accounts for 78.9%. Subway construction is a very large project, one of the key aspects is to deal with the large amount of sludge generated during the construction process, due to the limited capacity of temporary storage of sludge at each construction station, if the muck cannot be transported out of the station in time, it will lead to disruption of the subway construction.

For this reason, most of the subway lines under construction have set up muck treatment plants to handle the muck generated by the construction. If there is a lack of unified coordination and scheduling between the construction parties of each station and the muck treatment plant regarding the transportation of muck, it is easy to have problems such as congestion at the unloading point of the treatment center or long periods of machine idleness, which seriously affects the treatment efficiency of the treatment center. Seriously affects the efficiency of muck transfer and the treatment efficiency of the muck treatment center. After investigation and research, it was found that since the urban main roads would have a no-traffic policy in the morning and evening peaks, the stations would be swarmed with muck trucks at the end of the no-traffic hours, causing congestion in the unloading area. While other hours there will be no muck trucks for a long time, resulting in idle disposal machines. Based on this, for the muck transportation link, the waiting time of the vehicle and is considered comprehensively, the subway residue transportation scheduling model is established with the objective of minimum waiting time, the algorithm is designed to solve the model, and the optimization scheme of the residue truck transportation scheduling is given to reduce the uneven time of the muck truck in the treatment plant, so as to improve the transportation efficiency and the treatment efficiency.

Experts and scholars at home and abroad have done a lot of research on vehicle scheduling: G.B.Dantzig and J.H.Ramser[1] first proposed the vehicle scheduling problem for logistics distribution in 1959.Zong Haoyang[2] in view of the problem of distributing vehicles in batching plant proposes a multi-batching plant coordinated dispatching model, and establishes the corresponding mathematical model with the goal of the shortest waiting time of construction site and the shortest waiting time of concrete mixer at the site, and solve the problem by using the genetic algorithm. Matsatsinis[3] proposes a mathematical model for distribution of commercial concrete production systems with time window constraints for construction sites. Gao Zhibo[4] developed a bi-level objective programming model based on the minimum total cost under the vehicle loading condition and constraints of vehicle type and the time window, in response to the shortcoming that many models and algorithms of vehicle routing problem were designed for single-type vehicle instead of multi-objective and multi-type vehicle with time window. Feng C W [5] et al. simulated the distribution scheduling problem of a single commercial concrete plant supplying multiple construction sites using a general genetic algorithm. Tang Jun[6] proposed an immune algorithm based on optimization solution of Vehicle Routing Problem with Time Windows that expounded the mathematical model of scheduling problem and the frame of immune multiobjective optimization algorithm to solve multi-objective Vehicle Routing Problem with Time Windows. Lin Taosheng[7] in view of the characteristics of large concrete demand and tight construction period brought by the simultaneous commencement of multiple projects in the region, attributed it to the production and transportation collaborative scheduling problem of multiple factories supplying multiple construction sites, considered the constraints of initial setting time,pouring interruption interval, vehicle fuel consumption, vehicle waiting penalty cost and pouring interruption penalty cost and established an optimization model with the lowest total transportation cost as the goal. Qu Yuehua[8] constructs 4 cold chain logistics distribution network optimization models on whether the number of line customers is limited or not, and whether delivery and pickup are carried out at the same time or not based on the main factors influencing the quality of dairy products classification.

In summary, the research on vehicle scheduling mainly focuses on logistics distribution and public transportation scheduling, and the research is mostly on one-point-to-multi-point logistics methods, and various algorithms are used to solve them. Many scholars make optimization improvements to the traditional genetic algorithm, and refine the actual problem into a model, and apply the co-evolutionary strategy of genetic algorithm to solve it, achieving good results. There are relatively few studies for multipoint-to-point logistics methods. In the study of multi-objective model solution with time window, there are more studies for ready-mixed concrete transportation vehicle scheduling, but lack of studies for subway residue soil transportation scheduling, so the study of optimization of subway residue soil transportation scheduling is of great importance.

2. The establishment of muck transportation scheduling model

2.1 Problem Description

The problem of cooperative scheduling of subway construction muck transportation vehicles considering the prohibited hours can be described as follows: generally the transportation of subway construction muck is carried out by dispatching the same type of muck trucks from multiple construction stations to a single muck treatment plant. The transportation state of the muck truck will directly affect the transportation efficiency and processing efficiency, and there are three main states in the transportation process of the muck truck as follows.

State 1: The muck truck arrives at the construction treatment plant just as the previous truck carrying out the transport task has finished unloading and leaves the plant, and can start unloading immediately upon arrival. This is the most ideal state of distribution:

State 2: If a muck truck arrives at the treatment plant while a muck truck is unloading or waiting to unload, it needs to wait until the previous vehicle has completed its unloading operation and leaves the treatment plant before starting to unload. In this case there is a vehicle waiting time for the muck truck, which will have an impact on the transportation efficiency.

State 3: When the muck truck arrives at the muck treatment plant, the previous truck carrying out the transportation task has finished unloading and driven away from the treatment plant for some time, in this case the muck truck can start unloading immediately upon arrival, but the treatment plant has a waiting time, which will have an impact on the treatment efficiency.

At the same time, according to the urban main road traffic restriction policy, muck trucks are prohibited from driving on the road during the specified hours. Therefore, the problem of minimizing the waiting time of vehicles and the waiting time of dumping plants while satisfying the road restrictions is the problem to be solved in this study.

2.2 Set up hypothesis conditions

Through the above analysis, it can be seen that the essence of the vehicle scheduling problem of subway construction residue transportation considering the prohibited hours is a vehicle scheduling problem with time windows. The problem in the actual transportation process is relatively complex, for example, the route, traffic and many other factors will have a certain impact on the driving process of the muck truck, in order to facilitate the solution, the following assumptions need to be made about the actual problem:

(1) Consistent type of dump trucks used at all construction stations;

(2) The location of each construction station and muck treatment plant is fixed, so the travel distance and travel time are fixed values, without considering the influence of path selection, unexpected accidents and vehicle load on them;

(3) The loading and unloading times are the same for different types of muck;

(4) Muck trucks depart immediately upon instruction;

(5) After the muck truck has finished unloading, it immediately returns to the construction station to which it belongs;

(6) If the muck truck completes unloading and it happens to be a prohibited period or it is unable to return to the construction station before the prohibited period begins, it waits at the treatment plant for the end of the prohibition;

(7) If the muck truck receives the instruction and it happens to be a prohibited period or it cannot reach the treatment plant before the beginning of the prohibited period, it will wait for the end of the prohibition at the construction station.

All time points of this model are expressed in minutes, while assuming a time axis with a starting point of 0000min and an end point of 1440min, and all time points of the model are expressed on the time axis.

2.3 Determination of relative parameters

Table 1: Relevant Parameter

symbol	meaning
ZC_{ik}	Time point of loading of the kth muck truck dispatched from station i to the muck treatment plant
FC_{ik}	The departure time point of the kth muck truck dispatched from station i to the muck treatment plant
DD_{ik}	The arrival time point of the kth muck truck dispatched from station i to the muck treatment plant
KF_{ik}	The time when the kth muck truck dispatched from station i to the muck treatment plant finishes unloading and starts returning
FH_{ik}	Point in time when the th vehicle dispatched from station to the muck treatment center returns to the station
KX_{ik}	The point in time when the kth muck truck dispatched from station i to the muck treatment plant starts unloading
ZCT_i	Loading time required for muck trucks dispatched from station i to the muck treatment plant
YST_i	Transportation time required for a muck truck dispatched from station i to a muck treatment plant to reach the treatment plant
XLT_i	The time required to unload a muck truck dispatched from station i to a muck treatment plant upon arrival at the treatment plant
FHT_i	Time required to return to station i from the muck treatment plant
VWT_{ik}	Waiting time for the kth muck truck dispatched from station i to the muck treatment plant
FWT_{ik}	Time for the treatment plant to wait for the kth muck truck dispatched from station i to the muck treatment plant

FIT	Maximum interval between two successive transportation allowed by the muck treatment plant
VIT	Maximum waiting time allowed for the vehicle
M_i	Single-day muck output at station i
I	Number of construction stations
m	Muck truck capacity
S_i	Number of transport vehicles in station i
VOT_{ik}	Travel time of kth muck truck from station i to muck treatment plant
TSS	Start time of restricted period
TSE	End time of restriction period

The relevant parameters defined for each construction station and muck treatment plant are shown in Table 1.

2.4 Definition of objective function

Define the objective function as follows:

$$\min Z = \sum_{i=1}^{I} \sum_{k=1}^{\left\lceil \frac{M_i}{m} \right\rceil} VWT_{ik}, \quad (1)$$

$$\min Z = \sum_{i=1}^{I} \sum_{k=1}^{\left\lceil \frac{M_i}{m} \right\rceil} FWT_{ik\circ} \quad (2)$$

That is, the sum of vehicle waiting time and machine waiting time is the shortest Set the constraints as follows:

$$FWT_{ik} \leq FIT \quad (3)$$

$$FC_k - FC_{k-1} \geq ZCT \quad (4)$$

$$S_i \geq 1 \quad (5)$$

$$VOT_{ik} \cap [TSS \ \ TSE] = \emptyset \quad (6)$$

where equation (3) is a constraint on the maximum allowable unloading interruption time at the treatment plant. The time that the treatment plant waits for the arrival of the muck truck cannot be greater than the maximum allowable unloading interruption time as a way to ensure efficiency; Equation (4) is a constraint on the interval between the departure times of two trucks before and after the construction station. The departure interval of two adjacent trucks in the same section cannot be less than the loading time, so as to ensure that each truck is fully loaded; Equation (5) is a constraint on the construction station vehicles. When a distribution task is received, it is guaranteed that at least one vehicle in the tender section; Equation (6) is a constraint on the time period of vehicles on the road to prevent vehicles from being on the road during the restricted hours.

3. Model solving algorithm design

Genetic Algorithm (GA) is a parallel search algorithm based on biological laws and natural genetic mechanisms. First proposed by Professor J.Holland[9] in 1975, the genetic algorithm was used to solve the VRP with great randomness when performing crossover and variation, and the algorithm had disadvantages such as easy premature maturity and slow convergence, so many scholars have made relevant improvements to the genetic algorithm.[10][11][12][13][14]

3.1 Chromosome coding

The problem studied in this paper has more decision variables and the constraints are more complex after considering the restricted period, so the algorithm in this paper uses real number coding, the length L of the chromosome is the sum of all vehicle runs, and L real numbers in the interval [0,1] are randomly generated.

3.2 Adaptation assessment

This study is a multi-objective optimization problem, and the Pareto optimal boundary method is commonly used to evaluate the objective function, but in order to facilitate the solution, two objective functions are combined into one, so the combined objective function is directly selected as the adaptation value function for adaptation evaluation in the process of solving using genetic algorithm. Usually the larger the value of the individual fitness function, the greater the probability of its inheritance to the next generation, and since this problem is seeking the shortest vehicle waiting and machine waiting time, the fitness value function takes the opposite of the objective function.

Each chromosome is calculated by the formula as follows:

☐*Mi* ☐ ☐*Mi* ☐

—

—

I ☐□ *m* ☐□ *I* ☐□ *m* ☐□

fit ☐☐(☐☐*a*☐*b*☐☐☐☐*VWT*

fit ☐☐(☐☐a☐b☐☐☐☐VWT_{ik} ☐☐☐ FWT_{ik})

i☐1 k☐1 i☐1 k☐1 (7)

where the value of ☐ is 109, a is the maximum number of wait time violations, and b is the maximum number of interval time violations.

Step 1: In the process of adaptation calculation, the decoding operation is first performed on the encoded chromosome, and the individual first gets the departure time arrival time of each muck truck for each transport. In order to avoid the restricted period, the departure time needs to be adjusted here. When the departure time is in the restricted period, you need to wait until the end of the restricted period to depart immediately, and when the arrival time is in the restricted period, the departure time is the end time of the restricted period minus the transportation time of this journey.

Step 2: Then, according to the arrival time of the dump truck at the treatment plant, the start unloading and end unloading times of each transport are obtained in the order of smallest to largest, respectively.

Step 3: Calculate the waiting time interval for any transport and the idle time of the muck treatment center, and calculate the adaptation of the chromosome.

3.3 Evolution of Genetic Operators

Step 1: Selection operator: The algorithm in this paper uses binary tournament selection, i.e., two individuals are selected from the population at a time, and then the one with the best adaptation value is selected to enter the progeny population and the operation is repeated until the new population reaches the original population size, with the same probability of each individual being selected.

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Step 2: Crossover operator: this paper's algorithm single-point crossover operator, that is, a randomly selected crossover point in the individual gene string, and then use the crossover point as a reference for partial gene exchange to generate a new chromosome.

Step 3 : Mutation operator: Adopt uniform mutation, firstly designate each gene in the individual coding string as a mutation point in turn, and for each mutation point generate a random number R to replace the original gene with the variation probability Pm corresponding to the range of gene values. $R \square r^{*} \square Ub \square Lb \square \square Lb$, r is a randomly generated integer between [0,1], and R($R \square R^{0} \square 0.1^{*} r^{*} \square Ub \square Lb \square \square Lb$) is chosen to replace the original locus in order to maintain the characteristics of the previous proceeding, increasing the diversity of the population.

Step 4: Repair operation: In order to improve the performance of the genetic algorithm, the chromosome is repaired for the individuals that violate the constraints to prevent the phenomenon of partial population leap.

Step 5 :Elitist strategy: In this paper, a strong elitist strategy is selected to improve the efficiency of the genetic algorithm by combining the parent population and the progeny population, ranking the fitness of each individual, and selecting individuals with the same population size to form a new population.

4. Example Analysis

4.1 Basic data

Table 2: Daily Sludge Output of Each Station

Station number	Daily muck output/m³	Station number	Daily muck output/m³
1	212.5	11	205.4
2	132	12	122.2
3	165.6	13	327.7
4	348.6	14	302.8
5	173.5	15	286.9
6	215.8	16	295.5
7	140	17	105
8	400.8	18	344.2
9	278.8	19	161.9
10	266.4	20	222.4

The data involved in this paper are obtained from the field research results of each construction station and muck treatment plant of a subway line under construction in Qingdao. There are 20 stations and one sludge treatment plant in this subway line under construction, and the daily sludge output of each station is shown in Table 2

All construction stations use four-axle muck trucks with a loading capacity of 26m³, the loading time is 10min per truck, the unloading time is 5min, the maximum waiting time allowed for muck trucks is 6min, and the maximum waiting time allowed for muck treatment plants is 7min.

Without considering the route selection problem and the influence of the external environment during vehicle driving, the vehicle transportation time to and from each construction station to the muck treatment center is measured as shown in Table 3.

Table 3: Vehicle-hours-traveled

Station Number	Transportation Time YST/min	Station Number	Transportation Time YST/min
1	48	11	18
2	40	12	16
3	44	13	14
4	39	14	12
5	34	15	9
6	29	16	13
7	26	17	15
8	23	18	17
9	24	19	19
10	21	20	17

4.2 ***Result analysis***

Table 4: Optimized Scheduling Scheme

Station number	Time of distribution	Time of departure [Number of vehicles required]
1	9	01:16[1] 06:12[2] 06:12[1] 09:16[2] 12:38[1] 12:53[2] 15:42[1] 19:30[2] 23:36[1]
2	6	00:00[1] 02:46[2] 3:56[1] 19:30[1] 19:37[2] 21:17[2]
3	7	00:40[1] 02:57[2] 12:50[1] 14:41[2] 20:33[1] 21:39[1] 22:49[2]
4	14	05:00[1] 06:12[2] 06:12[3] 09:00[1] 09:00[2] 09:10[3] 09:16[4] 12:23[3] 13:24[4] 15:51[1] 19:30[2] 21:57[4] 23:11[1] 23:22[2]
5	7	03:25[1] 03:39[2] 05:00[1] 05:59[2] 19:30[1] 21:29[2] 23:01[1]
6	9	00:30[1] 01:20[2] 03:24[1] 04:44[2] 09:20[1] 11:33[1] 11:46[2] 14:48[1] 20:19[2]
7	6	02:05[1] 04:57[2] 09:00[1] 12:36[1] 13:54[2] 14:53[1]
8	16	00:00[1] 01:10[1] 01:43[2] 02:40[3] 02:57[1] 03:12[1] 05:35[3]

		06:12[2] 10:41[2] 10:46[3] 13:47[2] 14:44[3] 15:53[2] 21:07[1] 22:14[2] 22:54[3]
9	11	02:32[1] 02:43[2] 05:57[1] 11:45[1] 12:15[2] 12:53[2] 15:42[1] 19:30[2] 20:41[1] 22:29[2] 23:41[1]
10	11	01:40[1] 05:34[2] 10:51[1] 11:26[2] 12:06[1] 12:56[2] 15:49[1] 19:30[2] 20:20[1] 21:17[2] 23:30[1]
11	8	04:15[1] 06:23[1] 10:33[1] 11:30[1] 14:10[1] 15:42[1] 21:41[1] 23:00[1]
12	5	00:58[1] 11:04[2] 12:01[1] 12:35[2] 20:35[1]
13	13	00:00[1] 00:00[2] 00:32[3] 03:00[1] 05:29[2] 09:00[3] 10:19[1] 13:37[2] 13:51[3] 14:49[1] 22:02[2] 22:46[3] 23:12[1]
14	12	02:10[1] 04:39[2] 05:00[1] 09:00[2] 13:45[1] 14:06[2] 15:39[1] 16:10[2] 19:30[1] 20:56[2] 21:34[1] 22:00[2]
15	12	01:17[1] 01:34[2] 03:29[3] 04:53[2] 11:22[3] 15:24[1] 15:34[2] 15:42[3] 19:30[1] 20:18[2] 20:43[3] 23:03[1]
16	12	04:37[1] 05:54[2] 10:02[3] 10:04[1] 10:25[2] 12:22[3] 13:41[1] 14:24[2] 21:05[3] 21:15[1] 23:30[2] 23:41[3]
17	5	05:50[1] 05:56[2] 10:44[1] 14:57[2] 21:22[1]
18	14	02:20[1] 02:32[2] 03:52[3] 03:57[1] 05:16[2] 06:06[3] 06:12[1] 09:00[2] 14:34[3] 19:30[1] 21:33[2] 22:14[3] 22:28[1] 22:30[2]
19	7	04:04[1] 05:02[2] 09:52[1] 12:01[2] 14:22[1] 15:17[2] 15:42[1]
20	9	00:40[1] 02:25[2] 03:33[1] 04:13[2] 10:12[1] 11:15[2] 12:31[1] 14:42[2] 22:43[1]

In the vehicle scheduling model of this paper, the MATLAB2020a platform was used for several attempts and improvements, and finally a population size of 100, a maximum evolutionary generation of 1000, a crossover probability of 0.6 and a variation probability of 0.01 were selected for simulation. After running, the iterated code is obtained, and the optimized departure time, arrival time and return time are obtained by decoding, and then the optimized schedule obtained is used to arrange the vehicles

required for the construction stations, and the number of vehicles required for each construction station is obtained.
As shown in Table 4.
Simulations show that the vehicle waiting time for all trucks does not exceed the maximum allowed waiting time in the case of the optimized scheduling scheme. The waiting time for all trucks to the muck treatment plant does not exceed the maximum waiting time allowed, and the optimized transportation scheduling arrangement is shown in Table 5. A total of 46 muck trucks are needed in the whole scheduling plan, with a total waiting time of 389 min for the vehicles and 175 min for the treatment plant; and the departure time, arrival time and return time all avoid the traffic restriction time, indicating that the scheduling plan is reasonably arranged.
Table 5: Transportation Scheduling Schedule

Station number / Number of vehicles required	Departure time /[Station vehicle number]	Arrival time	Return time	Vehicle waiting time/min	Machine waiting time/min
Station No.1	01:16[1]	02:04	03:02	0	5
/2 vehicles	06:12[2]	07:00	07:53	0	0
	06:12[1]	07:00	08:00	6	1
	09:16[2]	10:04	11:03	0	6
	12:38[1]	13:26	14:22	3	0
	12:53[1]	13:41	14:37	3	0
	15:42[1]	16:30	17:27	0	4
	19:30[2]	20:18	21:18	0	7
	23:36[1]	00:24	01:28	1	0
Station No.2	00:00[1]	00:40	01:32	0	7
/2 vehicles	02:46[2]	03:26	04:13	2	0
	03:56[1]	04:36	05:27	0	6
	19:30[1]	20:10	20:59	0	4
	19:37[2]	20:17	21:03	0	1
	21:17[2]	21:57	22:47	5	0
Station No.3	00:40[1]	01:24	02:15	0	2
/2 vehicles	02:57[2]	03:41	04:31	1	0
	12:50[1]	13:34	14:24	0	1
	14:41[2]	15:25	16:16	0	2
	20:33[1]	21:17	22:06	0	0
	21:39[1]	22:23	23:14	0	2
	22:49[2]	23:33	00:23	0	1
Station No.4	05:00[1]	05:39	06:25	2	0
/4 vehicles	06:12[2]	06:51	07:40	5	0
	06:12[3]	06:51	07:36	1	0

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	09:00[1]	09:39	10:23	0	0
	09:00[2]	09:39	10:24	0	1
	09:10[3]	09:49	10:34	1	0
	09:16[4]	09:55	10:41	2	0
	12:23[3]	13:02	13:47	1	0
	13:24[4]	14:03	14:51	0	4
	15:51[1]	16:30	17:18	4	0
	19:30[2]	20:09	20:54	0	1
	21:57[4]	22:36	23:24	4	0
	23:11[1]	23:50	00:38	0	4
	23:22[2]	00:01	00:47	2	0
Station No.5	03:25[1]	03:59	04:43	0	5
/5 vehicles	03:39[2]	04:13	04:54	0	2
	05:00[1]	05:34	06:14	1	0
	05:59[2]	06:33	07:16	4	0
	19:30[1]	20:04	20:47	4	0
	21:29[2]	22:03	22:47	0	5
	23:01[1]	23:35	00:18	4	0
Station No.6	00:30[1]	00:59	01:37	4	0
/2 vehicles	01:20[2]	01:49	02:26	3	0
	03:24[1]	03:53	04:29	0	2
	04:44[2]	05:13	05:52	5	0
	09:20[1]	09:49	10:27	4	0
	11:33[1]	12:02	12:40	4	0
	11:46[2]	12:15	12:49	0	0
	14:48[1]	15:17	15:53	2	0
	20:19[2]	20:48	21:23	0	1
Station No.7	02:05[1]	02:31	03:5	3	0
/2 vehicles	04:57[2]	05:23	05:55	0	1
	09:00[1]	09:26	10:03	6	0
	12:36[1]	13:02	13:38	5	0
	13:54[2]	14:20	14:53	2	0
	14:53[1]	15:19	15:53	3	0
Station No.8	00:00[1]	00:23	00:54	3	0
/3 vehicles	01:10[1]	01:33	02:06	5	0
	01:43[2]	02:06	02:34	0	0
	02:40[3]	03:03	03:32	1	0
	02:57[1]	03:20	03:50	0	2

	03:12[1]	03:35	04:03	0	0
	05:35[3]	05:58	06:30	4	0
	06:12[2]	06:35	07:08	5	0
	10:41[2]	11:4	11:37	5	0
	10:46[3]	11:9	11:42	5	0
	13:47[2]	14:10	14:38	0	0
	14:44[3]	15:07	15:41	6	0
	15:53[2]	16:16	16:51	0	7
	21:07[1]	21:30	21:59	1	0
	22:14[2]	22:37	23:06	1	0
	22:54[3]	23:17	23:45	0	0
Station No.9 /2 vehicles	02:32[1]	02:56	03:26	1	0
	02:43[2]	03:07	03:43	0	7
	05:57[1]	06:21	06:54	4	0
	11:45[1]	12:09	12:39	0	1
	12:15[2]	12:39	13:11	0	3
	12:53[2]	13:17	13:48	2	0
	15:42[1]	16:06	16:35	0	0
	19:30[2]	19:54	20:24	1	0
	20:41[1]	21:05	21:37	0	3
	22:29[2]	22:53	23:28	0	6
	23:41[1]	00:05	24:34	0	0
Station 10 /2 vehicles	01:40[1]	02:01	02:27	0	0
	05:34[2]	05:55	06:26	0	5
	10:51[1]	11:12	11:39	1	0
	11:26[2]	11:47	12:16	3	0
	12:06[1]	12:27	12:59	0	6
	12:56[2]	13:17	13:47	4	0
	15:49[1]	16:10	16:39	3	0
	19:30[2]	19:51	20:19	0	2
	20:20[1]	20:41	21:12	5	0
	21:17[2]	21:38	22:05	0	1
	23:30[1]	23:51	24:21	4	0
Station 11 /1 vehicles	04:15[1]	04:33	04:59	0	3
	06:23[1]	06:41	07:05	1	0
	10:33[1]	10:51	11:19	0	5
	11:30[1]	11:48	12:13	0	2
	14:10[1]	14:28	14:56	5	0
	15:42[1]	16:00	16:27	0	4

	21:41[1]	21:59	22:27	5	0
	23:00[1]	23:18	23:43	2	0
Station 12	00:58[1]	01:14	01:40	0	5
/2 vehicles	11:04[2]	11:20	11:44	3	0
	12:01[1]	12:17	12:40	2	0
	12:35[2]	12:51	13:16	4	0
	20:35[1]	20:51	21:14	0	2
Station 13	00:00[1]	00:14	00:34	1	0
/3 vehicles	00:00[2]	00:14	00:34	1	0
	00:32[3]	00:46	01:11	6	0
	03:00[1]	03:14	03:36	3	0
	05:29[2]	05:43	06:08	6	0
	09:00[3]	09:14	09:36	0	3
	10:19[1]	10:33	10:54	2	0
	13:37[2]	13:51	14:12	2	0
	13:51[3]	14:05	14:27	3	0
	14:49[1]	15:03	15:23	0	1
	22:02[2]	22:16	22:41	6	0
	22:46[3]	23:00	23:21	2	0
	23:12[1]	23:26	23:49	0	4
Station 14	02:10[1]	02:22	02:45	6	0
/2 vehicles	04:39[2]	04:51	05:11	3	0
	05:00[1]	05:12	05:34	5	0
	09:00[2]	09:12	09:30	1	0
	13:45[1]	13:57	14:19	5	0
	14:06[2]	14:18	14:39	4	0
	15:39[1]	15:51	16:13	5	0
	16:10[2]	16:22	16:41	0	2
	19:30[1]	19:42	20:04	5	0
	20:56[2]	21:08	21:26	1	0
	21:34[1]	21:46	22:04	1	0
	22:00[2]	22:12	22:34	5	0
Station 15	01:17[1]	01:26	01:43	3	0
/3 vehicles	01:34[2]	01:43	01:59	2	0
	03:29[3]	03:38	03:54	2	0
	04:53[2]	05:02	05:16	0	0
	11:22[3]	11:31	11:45	0	0

	15:24[1]	15:33	15:49	2	0
	15:34[2]	15:43	16:01	4	0
	15:42[3]	15:51	16:06	1	0
	19:30[1]	19:39	19:57	4	0
	20:18[2]	20:27	20:46	5	0
	20:43[3]	20:52	21:12	6	0
	23:03[1]	23:12	23:26	0	0
Station 16	04:37[1]	04:50	05:10	2	0
/3 vehicles	05:54[2]	06:07	06:28	3	0
	10:02[3]	10:15	10:39	6	0
	10:04[1]	10:17	10:37	2	0
	10:25[2]	10:38	11:03	0	7
	12:22[3]	12:35	12:57	4	0
	13:41[1]	13:54	14:14	2	0
	14:24[2]	14:37	15:01	6	0
	21:05[3]	21:18	21:38	0	2
	21:15[1]	21:28	21:48	0	2
	23:30[2]	23:43	24:03	0	2
	23:41[3]	23:54	24:13	0	1
Station 17	05:50[1]	06:05	06:26	1	0
/2 vehicles	05:56[2]	06:11	06:32	1	0
	10:44[1]	10:59	11:24	5	0
	14:57[2]	15:12	15:35	3	0
	21:22[1]	21:37	21:59	2	0
Station 18	02:20[1]	02:37	03:00	0	1
/3 vehicles	02:32[2]	02:49	03:15	4	0
	03:52[3]	04:9	04:32	1	0
	03:57[1]	04:14	04:39	0	3
	05:16[2]	05:33	06:00	5	0
	06:06[3]	06:23	06:48	3	0
	06:12[1]	06:29	06:53	2	0
	09:00[2]	09:17	09:45	6	0
	14:34[3]	14:51	15:13	0	0
	19:30[1]	19:47	20:13	4	0
	21:33[2]	21:50	22:16	4	0
	22:14[3]	22:31	22:54	1	0
	22:28[1]	22:45	23:08	1	0
	22:30[2]	22:47	23:09	0	0
Station 19	04:04[1]	04:23	04:51	4	0

/2 vehicles	05:02[2]	05:21	05:48	3	0
	09:52[1]	10:11	10:35	0	0
	12:01[2]	12:20	12:44	0	0
	14:22[1]	14:41	15:06	1	0
	15:17[2]	15:36	16:02	0	2
	15:42[1]	16:01	16:26	0	1
Station 20	00:40[1]	00:57	01:24	5	0
/2 vehicles	02:25[2]	02:42	03:8	4	0
	03:33[1]	03:50	04:17	0	5
	04:13[2]	04:30	04:58	6	0
	10:12[1]	10:29	10:52	1	0
	11:15[2]	11:32	12:00	6	0
	12:31[1]	12:48	13:16	6	0
	14:42[2]	14:59	15:25	4	0
	22:43[1]	23:00	23:24	2	0

5. Conclusion

In this paper, for the problems of muck transportation in subway construction, the optimization model of muck transportation time scheduling with the shortest vehicle waiting time and treatment plant waiting time is established considering the urban main road restriction policy, and solved by using improved genetic algorithm. And an example of a subway line under construction in Qingdao is analyzed, and the optimized scheduling scheme is obtained by verification. The total vehicle waiting time in the obtained scheduling scheme is 389 min, the total treatment plant waiting time is 175 min, and 46 vehicles are required. All transportation trips do not exceed the maximum allowed vehicle waiting time and the maximum treatment plant waiting time, and the departure time, arrival time and return time all avoid the restricted time, which effectively verifies the feasibility of the model and algorithm.

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