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Evaluation and Optimization of Line Layout of Bus Hub

Bintao Liu[1]

[1]School of Transport, Shanghai Maritime University, Shanghai 201306, China.

Abstract

With the development of the city's economy, the population of the city has increased dramatically, and urban traffic problems have become a part that cannot be ignored in urban development. As a particularly important part of the urban public transportation system, bus hub has a considerable impact on the public transportation service level of the entire city. This article takes Ningbo Railway Station South Square Station as an example. In view of the current bus line layout, it is not convenient for passengers to choose the platform waiting, which limits the scope of passengers' choice. An optimization model between the bus line and the platform is established. degree of inconvenience is taken as the value of the objective function, and finally the model is solved by genetic algorithm.

Keywords

Bus hub, degree of inconvenience, line layout, optimization,genetic algorithm.

1. Introduction

A large-scale bus hub station can generally accommodate more than a dozen or even dozens of bus lines. In order to have a separate bus platform for each line, it is necessary to ensure that the starting station of the bus hub has a large enough space. However, the starting station of a large bus hub is usually located in a place where a variety of transportation modes are transferred and the geographical location is relatively superior, so generally speaking, it is necessary to use as small an area as possible to meet the operation of the starting station of the bus hub. On the other hand, passengers in choose the platform, there will be any inconvenience caused, such as: passengers to a certain spot to see that there are two or more lines can be reached, and the time required to take these few lines difference not very big, so the passengers will need to pay attention to several routes at the same time whether the vehicle arrive station, and when these platform distance far away, it may not be able to timely notice vehicle arrive station, restrict the selection scope of passengers, to miss the train, greatly increased the cost of travel time, at the same time reduces the bus service level.

Zheng et al. [1] proposed that entropy weight-close value method was adopted to select the lines entering the bus hub, and a mathematical model of platform layout optimization within the multi-objective bus hub was constructed based on the optimization objectives of passenger movement cost, minimum departure time interval cost and maximum platform correlation degree, and a multi-objective genetic algorithm was designed to solve the problem.

Xu [2] puts forward optimization theory and method is applied to solve the public transportation hub station line and reasonable allocation of parking space, aiming at the problem of public transport hub station lines and parking characteristics to establish mathematical model, gives the algorithm of solving the model, and according to the algorithm program, get the optimal solution of the problem, so as to improve the operating efficiency of bus hub.

In the study of the utilization rate of the platform in the bus hub, Chen and Deng[3] put forward the problem of rational allocation of bus lines and platform parking Spaces, in order to avoid the congestion of the platform caused by the allocation of less parking Spaces in some lines at

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a certain time, while the allocation of parking Spaces in some lines caused more waste of resources. It is necessary to reasonably allocate each line to each platform according to the operation situation of different bus lines, different bus distribution types and other factors.

Li [4] put forward the setting method of bus hub and the mathematical model of the problem of rational optimal configuration between bus line and platform, and applied simulated annealing algorithm to solve the problem. Finally, an example analysis showed that the method had strong practicability.

2. The Optimization Model

2.1. Mathematical Model

The modeling method used is to multiply the number of intervals between the platforms of line i and line j by the number of common stops between the two parties. The specific model is as follows:

$$\min Y = \sum_{ij} a_{ij} \left| x_i - x_j \right| \tag{1}$$

Constraint:

$$\underset{i}{sum}\left(x_i == k\right) = c_k \ \left(k = 1, 2, 3, \ldots\right) \tag{2}$$

$$\left(x_i == k\right) = 1 \ \left(x_i = k\right) \tag{3}$$

$$\left(x_i == k\right) = 0 \ \left(x_i \neq k\right) \tag{4}$$

Symbol and parameter meanings:

i , j : platform number, i= 1,2,3...; j= 1,2,3...;

x_i , x_j : platform number of each line;

a_{ij} : number of joint stops between line i and line j;

k: number of lines called at each platform, k=1,2,3,...;

c_k : given the number of docked lines corresponding to each platform.

Model specification:

(1) The objective function represents the product of the number of common stations of the i-th line and the J-th line and the number of intervals between these two lines. The absolute value is to prevent the occurrence of negative cases, which is not conducive to judgment.

(2) In constraint (2), judge whether the platform number of line I is the same as the platform number of line K. If it is the same, then =1, and the difference is 0;

(3) Constraint (2), (3) and (4) ensure that the bus lines allocated by each platform are the same as the number of lines accommodated by each platform.

2.2. Case Analysis

The ningbo Railway Station south Square bus terminal station has 26 lines starting from, each going in different directions. Through the investigation, the trend diagram of these 26 routes (Fig. 1) is summarized, from which the route of each route and the relationship between different routes can be observed. The layout of ningbo Railway Station South Square bus station

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is a u-shaped opening to the south (Fig. 2). Buses enter the platform from the u-shaped port on the left, then stop in front of the stopped platform to wait for passengers, and then leave the platform along the inside edge of the U-shaped field.Through the investigation of 26 lines of ningbo Railway Station South Square bus hub station, we get all the stops that each line passes through, and then through the comparison of the distance of each station, we get the same or similar stops between each of these lines (Table 1).

Fig 1. Bus route map

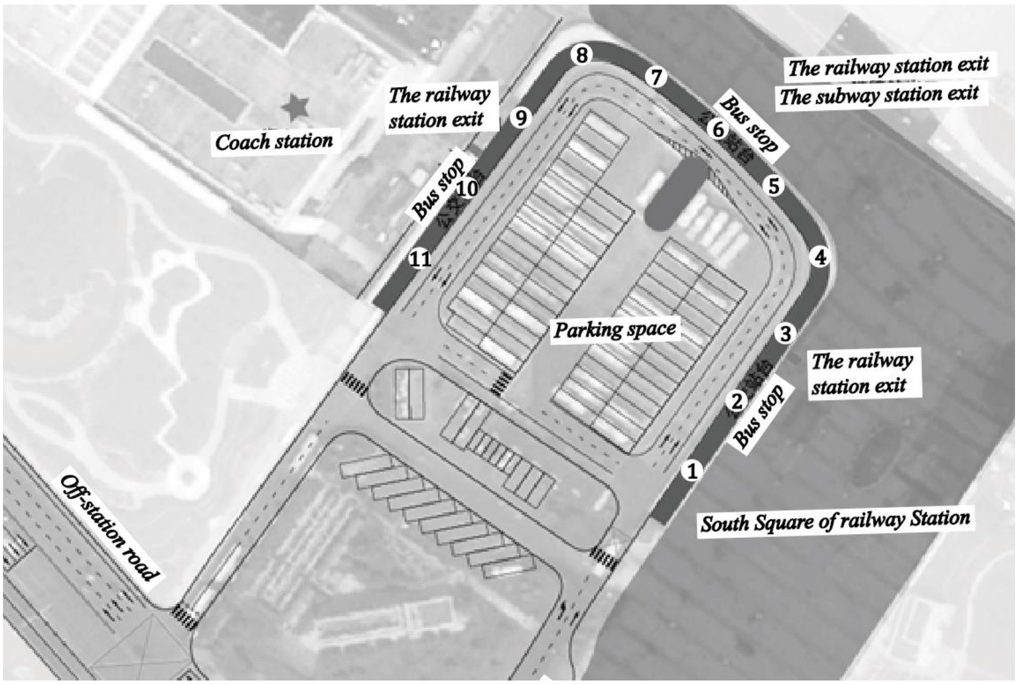

Fig 2. Layout of bus platform

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202012_3(12).0047

Table 1. The number of repeated stops on the bus route

Bus lines	30	514	1	301	906	916	988-2	354	10-1	10-2	81	...
30	2	4	2	2	1	1	1	2	2	1	2	...
514		1	1	1	1	1	1	6	6	1		...
1	1		1	2	1	1	4	2	2	1	1	...
301	1	1		1	1	1	1	4	4	1	1	...
906	1	2	1		3	4	4	1	1	7	1	...
916	1	1	1	3		1	1	1	1	2	1	...
988-2	1	1	1	4	1		2	1	1	1	1	...
354	1	4	1	4	1	2		1	1	1	1	...
10-1	6	2	4	1	1	1	1		23	3	6	...
10-2	6	2	4	1	1	1	1	23		3	6	...
81	1	1	1	7	2	1	1	3	3		1	...
...	...	...	...	...	...	...	...	...	...	...		...

3. Genetic Algorithm Solves the Modeld

3.1. Algorithm Design

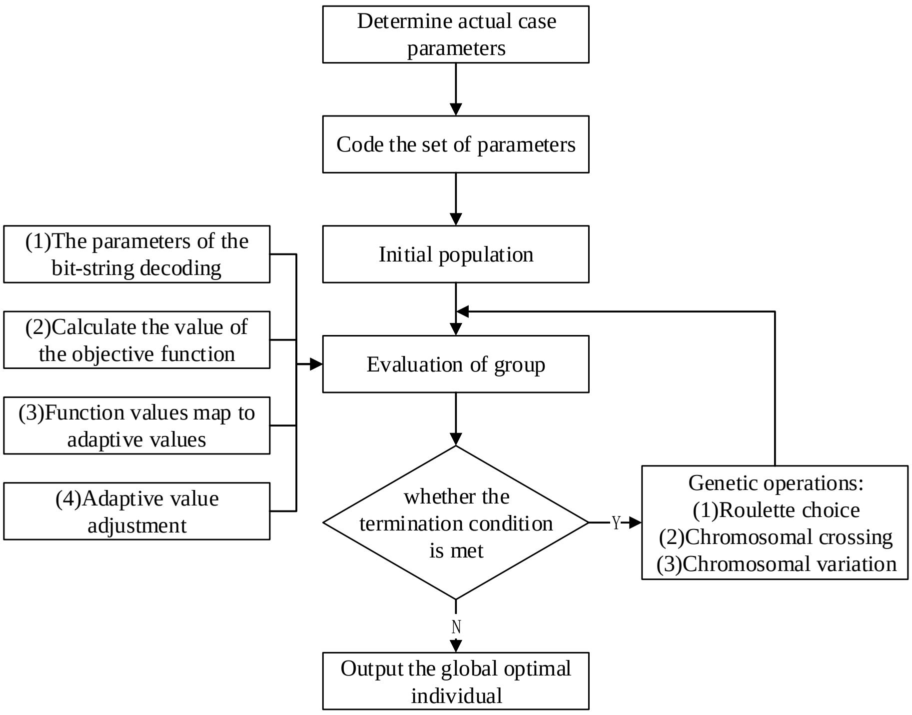

Fig 3. Algorithm flow chart

3.2. Fitness Function

The fitness function to be selected in this paper needs to be based on the objective function. Generally, the value of the fitness function requires that the larger the better, while the value of our objective function represents passenger dissatisfaction, so the smaller the better. Then, we set the reciprocal of the objective function as the fitness function of this model.

$$\max Z = \frac{1}{\sum_{ij} a_{ij} \left| x_i - x_j \right|} \quad (i, j = 1, 2, 3, \ldots 26) \tag{5}$$

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Constraint:

$$\underset{i}{sum}\left(x_i == k\right) = c_k \ \left(k = 1, 2, 3, \ldots 11\right) \tag{6}$$

$$\left(x_i == k\right) = 1 \left(x_i = k\right) \tag{7}$$

$$\left(x_i == k\right) = 0 \left(x_i \neq k\right) \tag{8}$$

The calculation process of individual fitness is as follows:

Step 1: Decode the individual's code to obtain the individual's phenotype (line layout scheme);

Step 2: Calculate the individual objective function value according to the layout plan of the line;

Step 3: Take the reciprocal of the objective function as the fitness of the individual. The higher the fitness value, the more likely an individual is to produce offspring, the more likely it is to produce new chromosomes, and the more likely it is to produce offspring that are closer to what we need.

3.3. Roulette Choice

The roulette selection method selected in this paper is to calculate the probability of each individual entering the next generation according to the proportion of the fitness value of all individuals in the population. This is a relatively common selection method. That is:

$$\text{The probability that chromosome A is selected} = \frac{\text{Fitness of chromosome A}}{\text{The sum of the fitness of all chromosomes}} \tag{9}$$

3.4. Chromosomal Crossing

Due to the constraint condition, the crossover method needs to be improved. We will of the father generation 1 four genes corresponding to generate random Numbers, and then compared with the fitness value of chromosome, if less than this value, just choose the genes, if greater than this value, to abandon the gene, and then will get genes according to the order in the new generation of DNA, the last parent 2 gene (where to leave with the parent generation 1 selected duplicate genes) according to the order of behind the parent 1 gene, so was born the new chromosome.

$$P_1 = [0, 1, 2,\ 3] \text{ (parent generation 1)} \tag{10}$$

$$P_2 = [3,\ 2, 1,\ 0] \text{ (parent generation 2)} \tag{11}$$

$$C_p = [\_,\ b, \_,\ b] \text{ (select points from parent generation 1)} \tag{12}$$

$$C_1 = [1,\ 3, \_,\ \_] \text{ (fill in the dot of parent 1 before the child first)} \tag{13}$$

$$C_1 = [0,\ 1, 2,\ 3] \tag{14}$$

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3.5. Chromosomal Variationk

In this paper, the original variation method cannot be used, because the given conditions limit the number of lines cannot be repeated, and the existing stations and lines cannot be changed. So a mutation method, in which two points are randomly selected on a piece of DNA and the two genes are swapped, can effectively avoid the problems caused by the original mutation. The details are as follows:

$$C_1=[1,\ \underset{*}{3},2,\ \underset{*}{0}] \tag{15}$$

$$C_1=[1,\ \underset{*}{0},2,\ \underset{*}{3}] \tag{16}$$

Marked * in (15) and (16) is a random mutation in which the two genes are swapped to produce a new gene.

3.6. The Example Analysis

The problem is programmed and solved by computer language.

Table 2. Program groups and parameter Settings

number	Crossover probability (Pc)	mutation probability (Pm)	initial population size	maximum number of iterations	objective function value (minY)
1	0.1	0.02	100	50	305
2	0.1	0.02	100	100	306
3	0.1	0.02	100	500	304
4	0.1	0.02	200	50	315
5	0.1	0.02	200	100	301
6	0.1	0.02	200	500	293
7	0.1	0.02	500	50	320
8	0.1	0.02	500	100	259
9	0.1	0.02	500	500	260

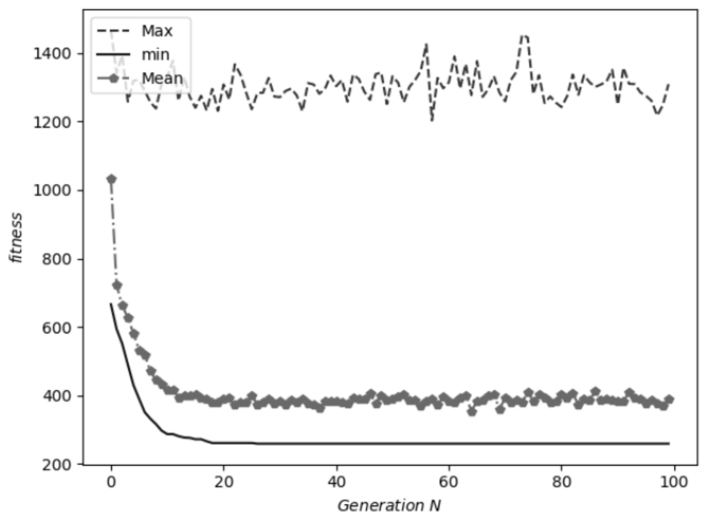

Fig 4. Example analysis Diagram (*minY=259*)

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Gen: 99 | best fit: 259.00
DNA [2 6 0 813 10 24 9 5 4 11 23 22 19 15 12 18 20 3 1 7 25 16 1417 21]
stop: [2 3 1 4 6 5 11 5 3 3 6 10 10 9 7 6 9 9 2 1 4 11 8 78 10]

4. Genetic Algorithm Solves the Modeld

Here will be degree of inconvenience to measure the minimum (259) as the DNA code decoding, get the optimal station and line layout plan, the plan with the original scheme comparison, obviously, the original plan of the calculated degree of inconvenience is 718, and the improvement scheme is obtained by genetic algorithm of passengers not convenient degree value is 259. It can be seen that the scheme obtained through genetic algorithm has a great improvement on the layout of bus station lines, as shown in Table 3.

Table 3. Scheme comparison

Numble	Bus Lines	The original	Heritage algorithm
1	30	1	2
2	514	1	3
3	1	2	1
4	301	2	4
5	906	3	6
6	916	3	5
7	988-2	3	11
8	354	4	5
9	10-1	5	3
10	10-2	5	3
11	81	6	6
12	987	6	10
13	988	6	10
14	514	7	9
15	625	7	7
16	633	7	6
17	692	8	9
18	634	8	9
19	638	9	2
20	518	9	1
21	819	10	4
22	106	10	11
23	156	10	8
24	179	10	7
25	883-2	11	8
26	161	11	10

5. Conclusion

In this paper, the route layout of bus hubs is optimized and a mathematical model is established to minimize the inconvenience of passengers in bus hubs and the global optimal solution is solved by genetic algorithm. The global optimal solution is to minimize the inconvenience of passengers and increase the convenience of bus stops. Through the example analysis of the bus

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route layout of Ningbo Railway Station South Square, we get the optimal route layout of the bus hub, and the scheme has strong practicability, greatly reduces the inconvenience of passengers, and plays a certain role in improving the bus service level.

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