Site selection of intercity Customized Passenger Transport Station Based on Immune Algorithm

Yanlin Cai
School of Traffic & Transportation, Chongqing Jiaotong University, Chongqing 400074, China

Abstract

Intercity customized passenger transport has continued to develop in recent years. Different from passenger lines, intercity customized passenger transport shifts change flexibly with passenger travel demand. The departure time and departure point settings depend on passenger travel demand. The setting of waiting points is not only related to passenger travel convenience, but also related to the service level of customized passenger transport. Taking the intercity custom passenger waiting point as the research object, the minimum distance cost from each waiting point to the travel demand point, the minimum fixed cost of the waiting point and the minimum operating cost of the enterprise are set as the objective function, and the distance from the waiting point to the demand point and the number of planned waiting points are set as the constraint conditions to construct the location model of the waiting point. Taking the travel demand of Chongqing and its districts and counties as an example, the immune algorithm is used to solve the model. At the same time, the difference between the travel demand under the influence of the COVID-19 and that without the COVID-19 in the future is considered, and the optimal fitness value and the final choice of the waiting point of the two cases are obtained respectively.

Keywords

Road passenger transport; customized intercity passenger transport; trip demand; allocation model; immune algorithms.

1. Introduction

In recent years, the inter-city customized passenger transport operation mode has developed rapidly in China. From the end of 2016, the Ministry of Transport issued the "Guiding Opinions on Deepening Reform and Accelerating the Transformation and Upgrading of Road Passenger Transport", which first proposed the concept of customized passenger transport, major cities across the country began to develop customized passenger transport, such as in January 2021, Zhejiang Province's "Anji Exchange Faster travel" opened customized passenger transport services from Anji to Hangzhou. Save passengers at least 60 minutes of travel time. In 2019, the Yinan Bus Station in Shandong Province cooperated with "Didi Travel" to realize two online and offline reservation methods, and opened a customized passenger line from Yinan to Linyi, achieving a seamless connection of "door to door and point to point". The construction of inter-city customized passenger transport operation mode is beneficial to meet the travel needs of passengers, and can provide passengers with a safe, comfortable and convenient travel environment. Therefore, the location of intercity customized passenger transport is particularly important. A reasonable location of waiting points can facilitate the planning of future customized passenger transport lines, thus saving passengers' travel time and reducing the operating costs of customized passenger transport enterprises. In this paper, mathematical models and relevant algorithms will be used to locate the waiting points of intercity customized passenger transport.

At present, there are abundant researches on customized passenger transport at home and abroad. Shen C et al. [1] and Wang C et al. [2] studied the optimization of customized bus routes and solved the optimization problem of customized bus routes by using different algorithms considering the travel rate of customized buses and the needs of passengers respectively. Gong M et al. [3] constructed a mixed integer nonlinear programming model based on customized bus network design, and used linearization method and particle swarm optimization (PSO) algorithm to optimize the network. Chen F et al. [4] constructed an optimization model of customized bus pick-up and unloading plan based on nonlinear dynamic programming, and used Gurobi 9.1.1 solver to solve the model and obtain the optimal scheduling scheme. Li Y et al. [5] consider the pricing of customized public transportation and ride-sharing, use the questionnaire results to determine the values of relevant parameters in the model to build a model and solve it, and get the factors to be considered in pricing. Zhan Bin et al. [6] studied the pricing strategy of customized passenger transport on intercity roads, used Logit model to describe the travel sharing rate of passengers, and applied the price elasticity theory of demand to obtain a reasonable fare range. Liu Na [7] proposed an optimization method for inter-city customized passenger transport operation routes based on demand clustering, combined with SOM algorithm to improve K-means algorithm, and obtained a reasonable amount and location of multiplication-drop points. Zheng Zikai [8] studied the optimization of the inter-city customized passenger transport operation mode, took into account the time cost and attendance rate modeling, and gave optimization suggestions according to the results.

The site selection of customized passenger terminal is the initial step of constructing customized passenger transportation network. There are many research methods for site selection. Kaya Ö et al. [9], Zu S et al. [10] and Li Weibin et al. [11] adopted fuzzy multi-criteria decision-making method based on GIS, YALMIP/CPLEX method and immune algorithm, respectively, to obtain a reasonable location of shared electric bus stations. Zhang X et al. [12] adopted image fuzzy sets (PFS) to collect information and solve the model to obtain the most appropriate offshore wind farm location. Lin R et al. [13] combined greedy algorithm and annealing algorithm to optimize genetic algorithm and proposed a hybrid solution of multiple algorithms to calculate the reasonable location of hydrogen refueling station. Yang Yulei et al. [14] calculated the location of the medical advance warehouse by using the third-generation non-dominated sorting genetic algorithm (NSGA-III). Zeng Yulong et al. [15] adopted the improved hybrid fruit fly optimization algorithm based on information exchange strategy to solve the model, and optimized the integration of site-inventory-distribution. Zhang Xinyi et al. [16] adopted the four-quadrant method and equal weight assignment method to select the best advantages as alternative points, and obtained the best construction location of first-aid resource sites.

Immune algorithms have many applications. Zhou Z et al. [17] used immune genetic algorithm to solve the closed trajectory cooperative target search problem of multiple UAVs. Zhang YC et al. [18] adopted an improved quadratic error measurement point cloud data reduction algorithm based on artificial immune algorithm to simplify the laser measurement data of geometric parameters of ring forging. Jiang Rongxing et al. [19] used immune algorithms to solve the problem of dynamic medical resource allocation. Chang Haowei et al. [20] proposed a detection method based on adaptive immune algorithm to detect the deception signals contained in the signals sent by the Beidou navigation satellite system. Immune algorithm has global search capability, diversity preservation mechanism and parallel distributed search mechanism, and is robust. In order to accurately and quickly find out reasonable intercity customized passenger waiting points, this paper uses immune algorithm to solve the location model considering passenger travel time cost and enterprise operating cost.

ISSN: 1813-4890

2. Problem Description

The selection of intercity customized passenger waiting points should consider many factors, first of all, to meet the needs of passengers, and minimize the distance between passengers to the waiting point. It is also necessary to meet the development needs of passenger transport enterprises and reduce costs as much as possible. Therefore, the following assumptions are made about the location of waiting points:

(1) The waiting point can meet the travel needs of passengers;

(2) A passenger chooses only one waiting point to travel;

(3) The travel demand of passengers is known;

(4) The number of planned waiting points is known;

(5) The location of each alternative waiting point, the number of customized passenger vehicles the enterprise plans to invest, land price, vehicle purchase cost and unit distance dispatching unit price are known.

3. Model Building

3.1. Symbol definition

Table 1 Symbol definitions

Symbol	Symbol definitions
F_1	The distance cost from each waiting point to the travel demand point
F_2	Fixed cost of waiting point and business operating cost
N	The sequence number of all required points is also the total number of antibodies
M_i	A collection of alternate waiting points whose distance from demand point i is less than s
ω_i	The quantity demanded at the demand point
d_{ij}	The distance between demand point i and its nearest waiting point
a_1	Waiting point construction land cost
a_2	The cost of purchasing customized passenger vehicles
Q	The company plans to invest in the number of customized passenger vehicles
n_1	Land construction cost billing cycle
n_2	Enterprise purchase custom passenger vehicle fee billing cycle
Z_{ij}	1 indicates that passengers at demand point i choose waiting point j to travel
	0 indicates that passengers at demand point i did not choose waiting point j to travel
h_j	1 indicates that point j is selected as the waiting point
	0 indicates that point j is not selected as the waiting point

A_v	Affinity function
F_v	Objective function
C	Take a larger positive number
$S_{v,s}$	Affinity between antibodies
$k_{v,s}$	The same number of digits in antibody v and antibody s
L	Antibody length

3.2. 3.2 Objective function

(1) The distance cost from each waiting point to the travel demand point is minimal

$$minF_1 = \sum_{i\in N}\sum_{j\in M_i}\omega_i d_{ij} Z_{ij} \tag{1}$$

(2)The fixed cost and operating cost of waiting point are the smallest

$$minF_2 = \frac{a_1}{n_1}\sum_{j\in M_i} h_j + \frac{a_2 Q}{n_2} \tag{2}$$

3.3. Constraint condition

(1)The number of planned waiting points shall not exceed the number of planned construction waiting points

$$\sum_{j\in M_j} h_j \le p \tag{3}$$

(2)Each passenger at the demand point can only choose one waiting point to travel

$$\sum_{j\in M_j} Z_{ij} = 1 \tag{4}$$

(3)Only the points set as waiting points can satisfy the demand points

$$Z_{ij} \le h_j , i \in N, j \in M_i \tag{5}$$

(4)Distance constraint from demand point to waiting point

$$d_{ij} \le s , i \in N, j \in M_i \tag{6}$$

4. Algorithm design

Jiang Xiaobing [21] introduced several types of immune algorithms, including general immune algorithm and negative selection algorithm. This paper uses the general immune algorithm, which was proposed by the early development of artificial immune system. The immune algorithm is a simple application of the immune mechanism and is relatively easy to implement. The flow chart of immune algorithm is shown in Fig. 1:

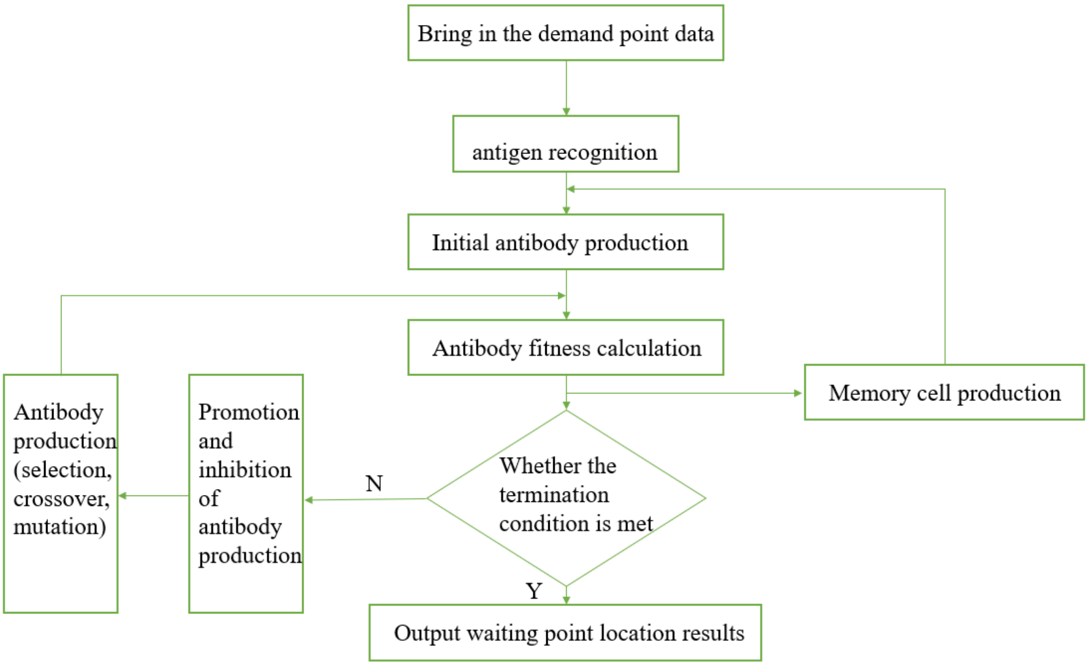

Fig.1 Immune algorithm flow chart

4.1. Production of initial antibody groups

Let each location scheme form an antibody of length p (p represents the number of waiting points), and each antibody represents the sequence of demand points selected as waiting points. For example, suppose there are currently 27 demand points, 1,2,... 27 represents the number of demand points, from which 8 are selected as waiting points. The antibody [1,4,6,7,8,15,17,25] represents a feasible solution, indicating that the demand points with serial number 1,4,6,7,8,15,17,25 are selected as waiting points.

4.2. Diversity evaluation of solutions

(1) Affinity between antibody and antigen

The affinity between antibody and antigen is used to represent the recognition degree of antibody to antigen [22]. Here, the affinity function is designed for the above waiting point location model as follows:

$$A_v = \frac{1}{F_v} \tag{7}$$

$$F_v = \sum_{i\in N}\sum_{j\in M_i}\omega_i d_{ij} Z_{ij} + \frac{a_1}{n_1}\sum_{j\in M_i} h_j + \frac{a_2 L}{n_2} - C\sum_{i\in N}\min\left\{\left(\sum_{j\in M_j} Z_{ij}\right) - 1,\ 0\right\} \tag{8}$$

The third term in the formula (8) means that the solution that violates the distance constraint is penalized.

(2) The affinity between antibodies and antibodies

The affinity between antibodies reflects the degree of similarity between antibodies. Zhang Ming-Qing et al. [23] improved the R continuous bit matching algorithm, and the improved R continuous bit matching algorithm can effectively improve the detection rate. This algorithm is used here to calculate the affinity between antibodies.

$$S_{v,s} = \frac{k_{v,s}}{L} \tag{9}$$

Suppose that the two antibodies are [1,2,3,4,5,6,7,8] and [1,2,3,4,10,11,12,13], four values are the same after comparison, and the antibody length is 8, so the affinity between them can be calculated as 0.5 according to the formula (9).

(3) Antibody concentration

Antibody concentration is the proportion of similar antibodies in the population, and the calculation formula is as follows:

$$C_v = \frac{1}{N}\sum_{j \in N} S_{v,s} \tag{10}$$

$S_{v,s} = \begin{cases} 1, & S_{v,s} > T \\ 0, & else \end{cases}$; T is a preset threshold.

(4) Expected reproduction probability

The expected reproduction probability of each individual in the population is determined by the affinity A_v between the antibody and the antigen and the antibody concentration C_v. The calculation formula is as follows:

$$P = \alpha \frac{A_v}{\sum A_v} + (1-\alpha)\frac{C_v}{\sum C_v} \tag{11}$$

α is a constant. As can be seen from the above formula, the higher the individual fitness, the greater the expected reproduction probability; The higher the individual concentration, the lower the expected reproduction probability. This encourages individuals with high fitness while discouraging individuals with high concentrations, thus ensuring individual diversity.

4.3. Immunization Procedure

(1) Selection: The selection operation is carried out according to the improved roulette selection mechanism proposed by Yi Zhengjun et al. [24] to enhance the optimization ability. The probability of an individual being selected is the expected reproduction probability calculated by formula (11).

(2) Crossing: A single point crossing method is used here for crossing operations.

(3) Variation: Variation is carried out by random selection of variation.

5. Case analysis: Take Chongqing City and various districts and counties as an example

According to the travel information filled in by passengers in the wechat travel mini program, there are 76 travel demand points in Chongqing and various districts and counties. The longitude and latitude information of each travel demand point can be obtained through the coordinate picker of Baidu Map open platform, and the demand point information can be counted by the mini program, as shown in Table 2:

Table 2 Requirement point information

Number	Waiting roll name	longitude and latitude	quantity demanded ω_i
1	Taojiapin (Wanzhou district)	108.403673,30.832441	36
2	Tangfang(Wanzhou district)	108.379458,30.873206	39
3	Gaoshan Bay(Fuling district)	107.369132,29.717311	28
4	Hongsheng Bridge(Fuling district)	107.403869,29.714114	34
5	Xiaojia Bay(Yuzhong district)	106.533002,29.548093	51
6	Linjiang Gate(Yuzhong district)	106.579308,29.565886	58

7	Xinshan Village (Dadukou District)	106.494917,29.488524	55
8	Yu Xin (Dadukou District)	106.484845,29.456333	54
9	Li Jiaping (Jiangbei District)	106.527955,29.568134	77
10	Wuli Store (Jiangbei District)	106.567059,29.588181	79
...	...	...	...

In order to facilitate the display of relative positions of travel demand points and planned waiting points, the longitude and latitude of all points are converted into points in Gaussian coordinate system using Gaussian coordinate conversion tool. After conversion, x and y coordinates of each point are shown in Table 3:

Table 3 Gauss coordinates of demand points

Number	Waiting roll name	X	Y
1	Taojiapin (Wanzhou district)	3474487.1440	36564381.0289
2	Tangfang(Wanzhou district)	3482095.5353	36561109.0019
3	Gaoshan Bay(Fuling district)	3342806.6596	36463926.3186
4	Hongsheng Bridge(Fuling district)	3341806.8329	36468935.2190
5	Xiaojia Bay(Yuzhong district)	3312095.4942	36392973.3822
6	Linjiang Gate(Yuzhong district)	3315035.7802	36401129.9776
7	Xinshan Village (Dadukou District)	3301200.5822	36386937.5356
8	Yu Xin (Dadukou District)	3294999.3793	36385243.0673
9	Li Jiaping (Jiangbei District)	3315806.2978	36392728.4159
10	Wuli Store (Jiangbei District)	3319457.9380	36398957.9591
...	...	...	...

The cost of waiting point construction should take into account the cost of materials, construction organization and measures, etc. In this paper, the construction cost of waiting point is estimated according to the construction cost of bus waiting point. The relevant data of enterprise costs are shown in Table 4:

Table 4 Enterprise cost data

Waiting point construction land cost a_1 (Yuan per square meter)	96268
Land charge billing cycle n_1(day)	30
Enterprise car purchase expenses a_2((Yuan per vehicle)	100000
Car purchase fee billing cycle n_2(day)	7
Number of vehicles planned for use Q(vehicle)	80

Since the demand obtained in Table 4 is the travel demand calculated under the epidemic situation, considering the development of customized passenger transport in the future without the epidemic situation, this paper adopts the exponential smoothing method to predict the population of the region where the travel demand point is located, and then it is converted according to a certain proportion as the future travel demand. The future travel demand of each waiting point is shown in Table 5:

Table 5 Future travel demand

Number	Waiting roll name	Future demand ω_i
1	Taojiapin (Wanzhou district)	121
2	Tangfang(Wanzhou district)	139
3	Gaoshan Bay(Fuling district)	117
4	Hongsheng Bridge(Fuling district)	152
5	Xiaojia Bay(Yuzhong district)	192
6	Linjiang Gate(Yuzhong district)	186
7	Xinshan Village (Dadukou District)	199
8	Yu Xin (Dadukou District)	176
9	Li Jiaping (Jiangbei District)	208
10	Wuli Store (Jiangbei District)	211
...	...	...

The data and cost data of each travel demand point are imported into the MATLAB immune algorithm program which is debugged in advance, and the location and distance of the waiting point are obtained.

Considering the large travel demand in the future, the number of vehicles purchased by the enterprise Q is increased to 100 when calculating the site selection results of waiting points under the future travel demand. 38 waiting points are planned to be built here. The calculated site selection results of waiting points are shown in Table 6.

Table 6 Site selection results

Different demand conditions	Location result point number	Correspond to the waiting roll name
Travel needs under the epidemic	8，4，74，31，38，14，6，60，52，13，27，40，61，65，50，47，23，15，63，56，29，24，30，67，59，43，72，53，35，46，73，58，57，22，42，9，41，1	Yuxin (Dadukou District), Hongsheng Bridge (Fuling District), Diya (Youyang Autonomous County), Jijiang Middle School (Jiangjin District), Industrial Park (Nanchuan District), Shipingqiao Street (Jiulongpo District), Linjiangmen (Yuzhong District), Lankai Garden (Zhongxian County), Century Five Dragon City (Wulong District), Chenjiaping Long-distance Station (Jiulongpo District), Banking Supervision Bureau (Qianjiang District), Science Popularizing Center (Bishan District), Sifang Jing (Yunyang County), Xizhuan Pan (Wushan County), Yahaoyuan (Liangping District), Muqiaowan (Kaizhou District), Yuanyang (Yubei District), Haitangxi (Nanan District), Tianqiao (Fengjie County), Vocational Education Center (Fengdu County), Waiborqiao (Changshou District), Yutong (Yubei District), Changshou Bus Terminal (Changshou District), New Station Bridge Intersection (Wuxi County), Hongxingqiao (Zhongxian County), Beicheng Lido (Tongnan District), Triangle Tower (Xiushan County), Yangguang Shui 'an (Chengkou County), Wenli High School (Yongchuan District), Yongjingwan (Rongchang District), Youyang No. 2 Middle School (Youyang Autonomous County), Dianyi Middle School (Dianjiang County), Chunhua (Dianjiang County), Shahe (Dazhu District), Jinxiu Jiangnan District A (Tongliang District), Lijiaping (Jiangbei District), Nanmen (Tongliang District), Taojiaping (Wanzhou District)
Future travel demand	19，62，51，1，20，58，4，54，76，29，68，2，60，10，48，41，6，5，56，74，42，31，45，18，52，	Tuowan (Qijiang District), Xinxian Hospital (Yunyang County), Wulong District Tourist Reception Center (Wulong District), Taojiaping (Wanzhou District), Jungle post (Qijiang District), Mat one Middle (Dianjiang County), Hongsheng Bridge (Fuling District), Chongyang Hotel (Chengkou County), Longyang village (Pengshui Autonomous County), Waiborqiao (Changshou District), Transportation Bureau Daqiaotou (Wuxi County), Tangfang

ISSN: 1813-4890

14，32，44，64，37，71，66，21，72，65，40，9，33	(Wanzhou District), Lankai Garden (Zhong County), Wulidian (Jiangbei District), No. 3 Bridge (Kaizhou District), Nanmen (Tongliang District), Linjiangmen (Yuzhong District), Xiaojiwan (Yuzhong District), Vocational Education Center (Fengdu County), Diya (Youyang Autonomous County), Jinxiu Jiangnan District A (Tongliang District), Jijiang Middle School (Jiangjin District), Team 69 (Rongchang District), Lighthouse (Beibei District), Century Five Dragon City (Wulong District), Shiping Bridge Street (Jiulongpo District), Shuangfu (Jiangjin District), Tongnan Railway Station (Tongnan District), No. 1 Bridge (Fengjie County), Nanchuan Middle School (Nanchuan District), Team 72 (Xiushan Autonomous County), Guanjiaxi (Wushan County), Haozikou (Dazu District), Triangle Tower (Xiushan Autonomous County), West Turntable (Wushan County), Science Center (Bishan District), Li Jiaping (Jiangbei District), Urban Council (Hechuan District)

According to the site selection results obtained in the table above, it can be seen that the selected waiting points cover almost every district and county in Chongqing, which can meet the travel needs of passengers in the city.

The calculated distance cost from each demand point to the site selection result point under the epidemic situation is shown in Table 7.

Table 7 Results of distance cost calculation

Result point / Demand point	8	4	74	...
1	253586.8	163444.1	208005.9	...
2	256775.8	167859.8	216163.9	...
3	92068.4	5107.7	163869.4	
...	...	...	...	...

The calculated distance cost from the demand point to the site selection result point under the future demand is shown in Table 8.

Table 8 Results of distance costing

Result point / Demand point	19	62	51	...
1	300304.6	56695.8	189809.6	...
2	305320.7	57493.8	196719.4	...
3	137609.8	216292.6	84707.6	...
...	...	...	...	...

The algorithm convergence curves under the two requirements are shown in Fig. 2 and Fig. 3.

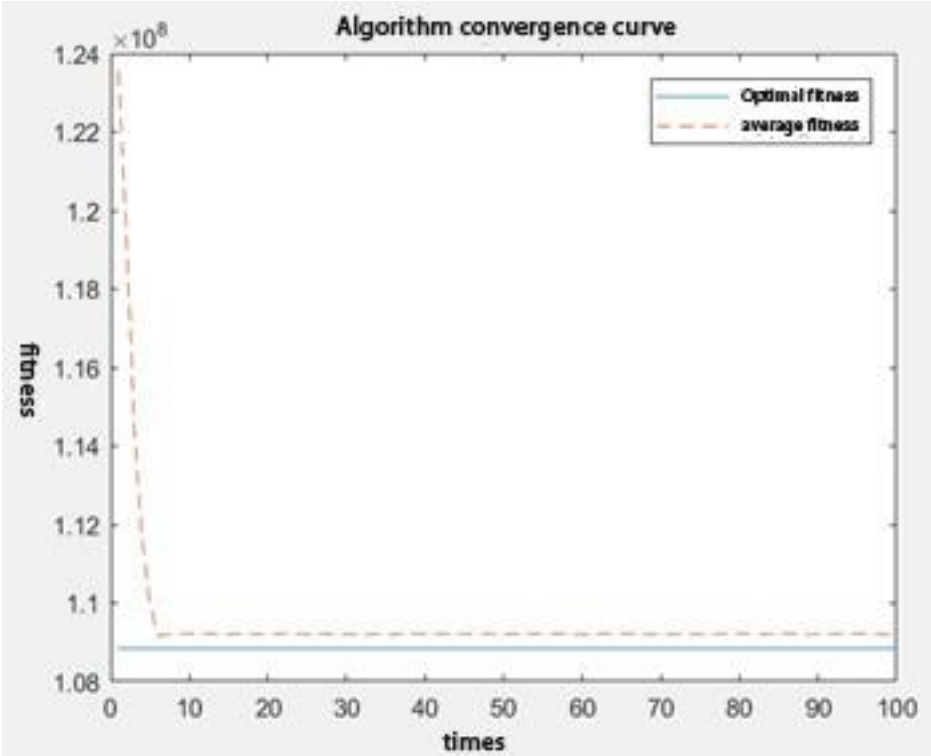

Fig.2 Convergence curve of demand income algorithm under epidemic situation

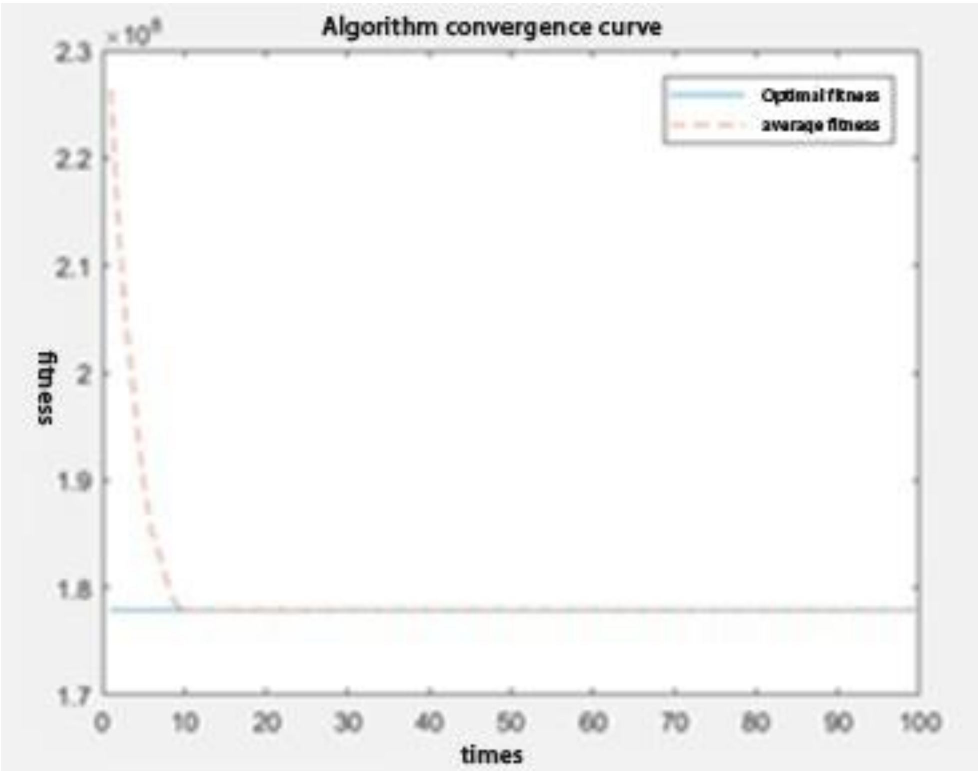

Fig.3 Future demand derived algorithm convergence curve

It can be seen from the two figures that the average fitness value converges in about 10 iterations, and the convergence is faster with small demand. The fitness here is the value of the affinity function given by equation (7), which is related to the objective function. This is because the objective function calculated by small demand is smaller than that by large demand, indicating that antibodies can recognize antigens quickly. That is, the demand points obtained from the survey are easily selected as waiting points.

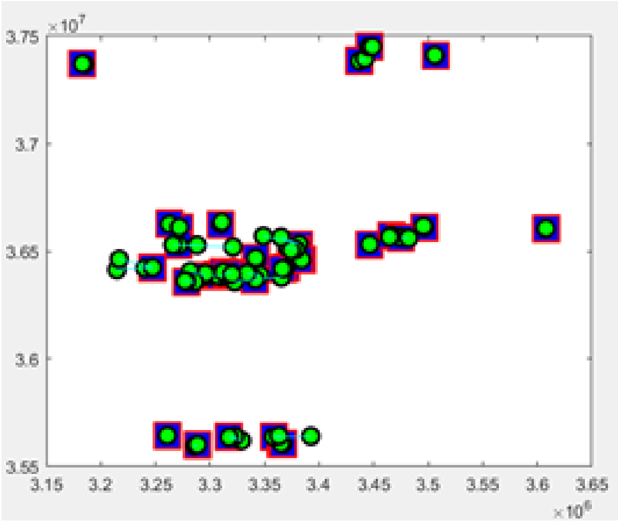

Fig.4 Bitmap of demand income points under epidemic situation

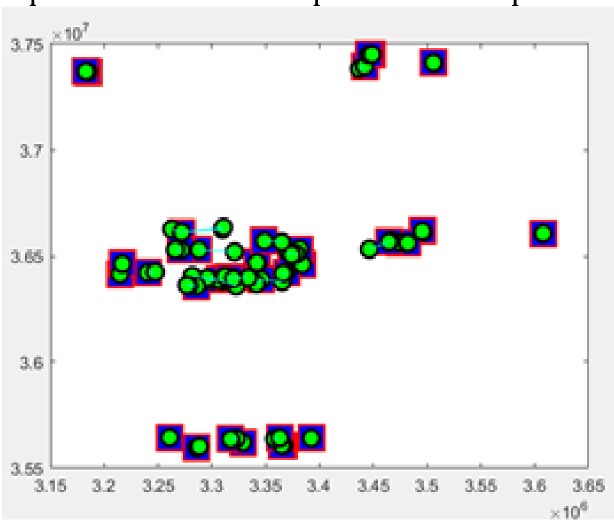

Figure 5. Bitmap of future demand income points

Fig. 4 and Fig. 5 are the relative positions of demand points drawn by MATLAB and waiting points selected by immune algorithm. The round points represent the travel demand points, and the round points with boxes around them represent the waiting points selected. Because there are too many points, the pictures look dense.

6. Conclusion

In this paper, the immune algorithm used to solve the location model is theoretically analyzed and the immune algorithm is globally convergent on the premise that the optimal individual of the previous generation is retained in the iterative process. Therefore, it can be seen from the convergence diagram of immune algorithm in this paper that the data introduced in this paper quickly converges. Although the algorithm convergence is a good result, the error of the data brought in should also be considered. The data obtained in this paper are based on the information filled in by passengers, and the location of waiting points can be queried on the map. The demand calculated according to the number of passengers filling in the information will change with different circumstances. For example, the epidemic situation in recent years has a great impact on passenger demand, so there is a certain error in the demand. The traffic generation forecasting model can be used to forecast the demand in the first of the four traffic stages to carry out more in-depth and accurate research. At present, this paper only constructs a site selection model for the waiting points of inter-city customized passenger transport and obtains a site selection scheme. In the future, for the optimization of inter-city customized passenger transport routes, it is also necessary to build a route optimization model and use the ant colony algorithm and other route optimization algorithms to optimize the route optimization results.

Reference

[1]Shen C, Sun Y, Bai Z, et al. Real-time customized bus routes design with optimal passenger and vehicle matching based on column generation algorithm[J]. Physica A: Statistical Mechanics and Its Applications, 2021, 571: 125836.

[2] Wang C, Ma C, Xu X D. Multi-objective optimization of real-time customized bus routes based on two-stage method[J]. Physica A: Statistical Mechanics and its Applications, 2020, 537: 122774.

[3] Gong M, Hu Y, Chen Z, et al. Transfer-based customized modular bus system design with passenger-route assignment optimization[J]. Transportation Research Part E: Logistics and Transportation Review, 2021, 153: 102422.

[4] Chen F, Peng H, Ding W, et al. Customized bus passenger boarding and deboarding planning optimization model with the least number of contacts between passengers during COVID-19[J]. Physica A: Statistical Mechanics and its Applications, 2021, 582: 126244.

[5] Li Y, Li X, Zhang S. Optimal pricing of customized bus services and ride-sharing based on a competitive game model[J]. Omega, 2021, 103: 102413.

[6] Zhan Bin, Wu Shuang. Research on Pricing Strategy of customized passenger transport on Intercity roads [J/OL]. Price Monthly :1-9[2022-04-06].

[7] Liu Na. Research on Optimization of inter-city customized passenger transport routes based on demand clustering. Chongqing: Chongqing Jiaotong University,2021.

[8] Zheng Zikai. Research on customized passenger transport mode of intercity road in Dayan District [D]. Guangzhou: South China University of Technology,2020.

[9] Kaya Ö, Alemdar K D, Atalay A, et al. Electric car sharing stations site selection from the perspective of sustainability: A GIS-based multi-criteria decision making approach[J]. Sustainable Energy Technologies and Assessments, 2022, 52: 102026.

[10] Zu S, Sun L. Research on location planning of urban charging stations and battery-swapping stations for electric vehicles[J]. Energy Reports, 2022, 8: 508-522.

[11] Li Weibin, Wu Fang, Zhang Yan. Research on location selection of shared electric vehicle network based on immune algorithm [J]. Journal of Lanzhou Jiaotong University,2022,41(01):34-39+51.

[12] Zhang X, Wang X, Yu S, et al. Location selection of offshore wind power station by consensus decision framework using picture fuzzy modelling[J]. Journal of Cleaner Production, 2018, 202: 980-992.

[13] Lin R, Ye Z, Guo Z, et al. Hydrogen station location optimization based on multiple data sources[J]. International Journal of Hydrogen Energy, 2020, 45(17): 10270-10279.

[14] Yang Yulei, Zhang Jin, Sun Wenjie, et al. Research on site-path problem based on medical advance warehouse under dynamic demand [J/OL]. Control and Decision :1-9[2022-04-06].

[15] Zeng Yulong, WANG Lin, WANG Sirui. Research on integrated optimization of location-stocking-distribution based on hybrid Fruit Fly optimization algorithm [J]. Operations Research and Management,2022,31(03):24-30.

[16] Zhang Xinyi, An Rui, Liu Yanfang. Accessibility analysis of first aid resources and site selection optimization in Wuhan [J]. Journal of Nanjing Normal University (Natural Science Edition),2022,45(01):49-54.

[17] Zhou Z, Luo D, Shao J, et al. Immune genetic algorithm based multi-UAV cooperative target search with event-triggered mechanism[J]. Physical Communication, 2020, 41: 101103.

[18] Zhang Y C, Wu M, Fu X B, et al. Reduced algorithm of laser measurement data for geometric parameters of ring forgings based on Artificial Immune Algorithm[J]. Measurement, 2019, 134: 527-538.

[19] Jiang Rongxing, Su Qiang. Dynamic allocation of medical resources during infectious disease outbreaks: a case study of the COVID-19 outbreak in Wuhan [J/OL]. Industrial Engineering and Management :1-21[2022-04-06].

[20] Chang Hao-Wei, Pang Chun-Lei, Guo Ze-Hui, et al. Deception signal detection Method based on adaptive immune algorithm [J/OL]. Systems Engineering and Electronics :1-10[2022-04-06].

[21] Jiang Xiaobing. PCB Routing System Optimization Based on Immune Algorithm [D]. Guangxi University,2013.

[22] Yu Lei, Shi Feng, Wang Hui, et al. MATLAB Intelligent Algorithm 30 Case analysis: 2nd edition [M]. Beijing: Beihang University Press,2015.

[23] Zhang Ming-qing, CHENG Jian, Kong Hong-shan, et al. Improvement of r Continuous Bit Matching Algorithm [J]. Computer Engineering and Design,2014,35(08):2650-2654.

[24] Yi Zhengjun, Han Xiaojing. An improved artificial bee colony algorithm with enhanced optimization ability [J]. Data Acquisition and Processing,2013,28(06):761-769. (in Chinese)