Research on Customized Passenger Route Optimization Based on Improved Genetic Algorithms

Ma Jun\textsuperscript{1,a}, Wu Hongzhou\textsuperscript{1,b}, Zhang Xiu\textsuperscript{1,c}, Zheng Huijuan\textsuperscript{2,d}, Chen Yufei\textsuperscript{2,e}

\textsuperscript{1}Department of Mechanical and Electrical Engineering, Zhengzhou University of Light Technology, Zhengzhou, Henan, China
\textsuperscript{2}Wanli Transport Co. LTD, Xuchang, Henan, China
\textsuperscript{a}email: majun@zzuli.edu.cn, \textsuperscript{b}email:1609976821@qq.com,
\textsuperscript{c}email: zhangxiu@zzuli.edu.cn, \textsuperscript{d}email:157170732@qq.com
\textsuperscript{e}email: wlyy202@126.com

Abstract: In view of the passenger travel demand changing from popularization to high quality and customization, a customized passenger route planning method with multi-departure point and multi-arrival point is proposed, and a customized passenger route optimization model with the minimum total cost for enterprise operation and passenger travel time is established. An improved genetic algorithm is proposed to solve the optimization model. Finally, the feasibility of the optimization method and the effectiveness of the improved genetic algorithm are verified by a practical case.

1. Introduction
In recent years, with the rapid development of social economy, people's travel needs have changed from popular to high-end, personalization and diversification. Customized road passenger transport service is a new mode of passenger transport service, which provides personalized and diversified travel options for passenger groups.

The key to the implementation of customized road passenger landing is how to provide passengers with efficient and diverse passenger routes at a lower cost. Passenger route planning traditionally belongs to Vehicle Routing Problem (VRP). Zhou Jiali et al.\textsuperscript{[1]} proposed an accurate expression method for the multi-mode traffic network facing roads, bus lines and subways. JALEL et al.\textsuperscript{[2]} studied the school bus route planning optimization model with the goal of minimizing the driving distance. SEYED et al.\textsuperscript{[3]} established a double-decker bus route planning strategy with the possibility of site selection and demand outsourcing. Ma Qinglu et al.\textsuperscript{[4]} introduced a variety of intelligent algorithms on the basis of artificial neural network to comprehensively optimize travel routes. However, the above researches mainly discuss passenger line planning from the perspective of macro-control, or aim to meet the non-immediate response demand and realize the traditional passenger line planning with the characteristics of mass travel spatial and temporal distribution. The basic strategy is to obtain the shortest path to the destination by establishing the start-point OD model. However, in the customized road passenger transport service model, the multi-starting point and multi-arrival travel demand of start-to-destination separation is the root cause of passenger transport service differentiation. At present, domestic and foreign researches on such route planning are still in the preliminary discussion stage\textsuperscript{[5-6]}. 
In Combined with the above background, this paper proposes a customized passenger service model, constructs a customized passenger line planning and optimization model with the minimum total cost, solves the optimization model through improved genetic algorithm, and finally verifies the effectiveness of the model and algorithm with a case.

2. Customized passenger transport route planning optimization modeling

In the customized passenger transportation service, it is necessary to minimize the customized passenger transportation line from the perspective of total cost. The total cost in the customized passenger line consists of two parts, one part is the operating cost of the enterprise, which consists of the vehicle departure cost and the vehicle running cost, wherein the vehicle operating cost includes the driving cost per vehicle and the stopping cost of the vehicle at the station; The time cost for passenger travel consists of the passenger's time cost in transit and the cost of stopping the vehicle. With the goal of minimizing the total operating cost and passenger travel cost, the customized passenger route optimization model is as following.

\[
\begin{align*}
\min C &= \lambda_1^m \sum_{m \in M} \sum_{k \in K} \sum_{i \in P} \sum_{j \in P} x_{ij}^{mk} + \lambda_2 \sum_{m \in M} \sum_{k \in K} \sum_{i \in P} \sum_{j \in P} s_{ij}/v + t \\
S &\text{t} \sum_{i \in P} \sum_{j \in P} \sum_{m \in M} \sum_{k \in K} x_{ij}^{mk} = 1 \quad \forall j \\
\sum_{i \in P} \sum_{j \in P} \sum_{m \in M} \sum_{k \in K} x_{ij}^{mk} &= 0 \quad \forall j, m, k \\
\sum_{i \in P} \sum_{j \in P} \sum_{m \in M} \sum_{k \in K} x_{ij}^{mk} &\leq A \quad \forall m, k \\
\sum_{i \in P} \sum_{j \in P} \sum_{m \in M} \sum_{k \in K} x_{ij}^{mk} y_{ij}^m &\leq B \quad \forall m, k \\
\sum_{i \in P} \sum_{j \in P} \sum_{m \in M} \sum_{k \in K} x_{ij}^{mk} s_{ij} &\leq L_2 \quad \forall m, k
\end{align*}
\]

In the above model, the equation (1) represents the objective function. Equation (2) is a constraint on the site, that is, each site is only accessed once. Equation (3) is to prevent the vehicle from staying restrained, that is, the vehicle must leave after visiting the site. Equation (4) represents the number of vehicles, that is, the maximum number of vehicles that complete all travel demand. Equation (5) is the number of docking sites, which is to avoid too many stops in a line. Equation (6) is the vehicle carrying capacity constraint. Equation (7) represents the line length constraint.

Each parameter in the above formula is described as follows: \( \lambda_1^m \) represents the unit starting cost of Model M vehicle; \( \lambda_2 \) Represents the running cost of the vehicle; \( \lambda_3 \) Represents the value of the passenger's time in the car; P represents the collection of sites; M represents the vehicle set and m represents the index; K represents the set of a certain car model, and k represents the index; Q represents the passenger flow collection, and q represents the index; \( S_{ij} \) Denotes the arc length from Station i to Station j; \( V \) is the speed of the vehicle; \( t \) stands for stop time; \( L_1 \) Represents the minimum line mileage; \( L_2 \) Represents the maximum line mileage; \( A \) represents the maximum number of cars; \( B \) represents the maximum number of stops in a line; \( E \) represents the maximum carrying capacity of a certain vehicle; \( x_{ij}^{mk} \) Denotes that if the arc of K path \((i, j)\) of m-type \( x_{ij}^{mk} \) vehicle is 1; otherwise, it is 0. \( y_{ij}^m \) Represents the passenger flow of \( m \) type vehicle \( k \) carrying \( q \) demand. Where, is the passenger’s time on the bus, which can be simplified according to the GDP per capita per hour in the locality\(^{[7-8]} \), namely: \( \text{Time value} = \frac{\text{GDP/total population}}{365\text{-statutory holidays}}/\text{working hours per day} \).
3. Improved genetic algorithms for customized passenger route optimization

The traditional genetic algorithm does not depend on the gradient and has strong robustness and global search ability, but it has the disadvantage of premature convergence. Aim to the problems, an improved genetic algorithm is designed. The overall process is shown in figure 1.

3.1. Encoding

First, the customized passenger route optimization model is initialized, including coding and population initialization. The coding method has an important influence on the solution of the optimal value. According to the characteristics of the model, natural number coding is used. A complete chromosome coding is: \{2, 6, 8, 9, 0, 1, 4, 7, 0, 3, 5, 10, 1, 11, 15, 13, 16, 0, 14, 17, 19, 0, 12, 18, 20\}. The chromosome contains three sub-paths, as shown in Figure 2.

\[ F_i = \frac{1}{C_i} \]  

(8)

Where \( C_i \) represents the objective function value of the i-th chromosome. The greater the fitness value \( F_i \), the stronger the adaptability of the chromosome. For chromosomes that do not meet the constraints, the fitness value is \( F_i = 0 \).

In order to speed up the convergence of the algorithm and avoid the local optimal solution, the nearest path method is used to access each station. Under the constraints of vehicle transport passenger flow constraints, vehicle transit site constraints, line length constraints, vehicle number constraints, and vehicle carrying capacity constraints, the initial population is evenly distributed into the solution space.
3.2. Crossing and mutation operations
Due to customized road passenger transport line optimization model adopted the boarding line encoding phase separation, and USES the path method for population initialization, recently may have formed the most sub paths gene, the standard genetic algorithm crossover operation is very difficult to keep the good genes, therefore, this paper designed a kind of most of sub path reserves the crossover operation method.

As shown in Figure 3 below, this method randomly generates two intersections, moves left or right at the same time to make them completely contain a sub path, and then completes the chromosome crossing operation in the way of sequential crossing. Since each chromosome contains two parts, namely, the boarding route and the disembarkation route, the two parts are corresponding during the crossover operation. First, two intersections are generated in the part of the disembarkation route of the chromosome, and then two intersections are generated in the part of the disembarkation of the chromosome. The two intersections are shifted to the right or left to include a sub path. Finally, the two intersections are crossed sequentially.

4. Case analysis
4.1. Enterprise Customized Passenger Line Planning
In this paper, combined with the urban and rural through train service of a passenger company's minibus, 12 passenger flow OD in two regions of Henan Province were selected to conduct empirical research on passenger travel at 24 stations during the period from 6 am to 8 am. The 24 stations were numbered according to the station distribution, and OD section information was plotted from the starting station, arrival point, OD section and the passenger flow of each OD section, as shown in Table 1.

Assign values to the parameters in the example, where the vehicle selects vehicles with 50, 40 and 30 passengers, ie E=50, 40 and 30; the cost of each vehicle is \( \lambda_1=300, 250 \) and 200 Yuan; average vehicle speed \( v=90 \text{km/h} \); vehicle stop time \( t=1/12 \text{h} \); vehicle hourly operation cost \( \lambda_2=250 \) yuan/h; vehicle time
value $\lambda_3=25$ yuan/h; line length minimum $L_1=100$km, Maximum line length $L_2=350$Km; The maximum number of cars $A=6$; The maximum number of stops per line $B=6$.

Table 1. OD Section Information.

| Departure station       | Arrival station           | OD section | Passenger flow (people) |
|-------------------------|---------------------------|------------|-------------------------|
| Pingdingshan Station    | Xiuwu County Station      | (1,15)     | 19                      |
| Jixian Station          | Jiaxian County Station    | (2,17)     | 15                      |
| Ye County Station       | Yuanyang County Station   | (3,20)     | 18                      |
| Yucheng County Station  | Fengqiu County Station    | (4,24)     | 13                      |
| Wuyang County Station   | Wuyi County Station       | (5,14)     | 14                      |
| Xuchang City Station    | Zhengzhou Station         | (6,16)     | 23                      |
| Linyi County            | Xinxiang County Station   | (7,18)     | 16                      |
| Luohe City Station      | Jiaozuo City Station      | (8,13)     | 20                      |
| Liling County Station   | Yanjin County Station     | (9,22)     | 16                      |
| Fugou County Station    | Kaifeng City Station      | (10,23)    | 19                      |
| Xihua County Station    | Zhongli County Station    | (11,21)    | 13                      |
| Zhoukou City Station    | Xinxiang City Station     | (12,19)    | 18                      |

L2=350km; the maximum number of vehicles is $A=6$; the maximum number of stops per line is $B=6$.

In order to verify the effectiveness of the algorithm and model, this paper uses the 2014b version of MATLAB software as a test platform. The numerical experiments were performed 10 times with the genetic algorithm improved by this paper and the standard genetic algorithm. The statistical results obtained are shown in Table 2. It can be seen from Table 3 that the optimal solution obtained by the two algorithms in this example is 18075 yuan.

Table 2. Improved Genetic Algorithms for Solving Statistical Results of Numerical Experiments.

| Algorithm               | Optimal solution | Average solution | Average deviation | Maximum deviation | Optimal solution Number |
|-------------------------|------------------|------------------|-------------------|-------------------|------------------------|
| Standard genetic algorithm | 18075.00         | 18287.50         | 1.2%              | 3.5%              | 2                      |
| Improved genetic algorithm | 18075.00         | 18138.00         | 0.3%              | 1.6%              | 7                      |

In Table 3 above, four parameters (mean solution, mean deviation, maximum deviation and the number of optimal solutions) are listed to illustrate the stability and efficiency of the improved genetic algorithm. Figure 7 shows the changes when the standard genetic algorithm and the improved genetic algorithm obtain the approximate optimal solution.

As can be seen from Figure 5, the improved algorithm can obtain the optimal solution in a very short time, showing obvious advantages and improved convergence performance, thus verifying the feasibility and effectiveness of the algorithm.

Figure 5. Relation between objective function and genetic algebra.
4.2. Optimization results analysis
This experiment verifies the algorithm of this paper from the feasibility aspect. The genetic algorithm is used to obtain the minimum total cost optimization goal, and the detailed information of the obtained line is shown in Table 3.

| Numbering | Driving route | Line length (Km) | Driving time (h) | Number of vehicles (vehicles) | Model (seat) |
|-----------|---------------|------------------|------------------|------------------------------|--------------|
| 1         | 3-7—20-18     | 208.9            | 2.48             | 1                            | 40           |
| 2         | 5-1-2—14-15-17| 224.9            | 2.83             | 1                            | 50           |
| 3         | 4-10—23-24    | 196.3            | 2.34             | 1                            | 40           |
| 4         | 12-11-9—21-22-19| 218.7            | 2.76             | 1                            | 50           |
| 5         | 8-6—16-13     | 201.4            | 2.40             | 1                            | 50           |

It can be concluded from the above table that the optimal path of the passenger route based on the minimum goal is five paths. The order of each customer site in the passenger plan is accessed by path 2 (model 1). Explain. Path 2: Starting point 5 - Site 1 - Site 2 - Site 14 - Site 15 - Endpoint 17.

5. Conclusion
The customized passenger line has the spatial distribution characteristics of multiple departure points-multiple arrival points, which are separated from each other. The customized total passenger transportation line is optimized with the minimum total cost as the goal, and the interests of enterprises and passengers are taken into consideration. The case study shows that the improved genetic algorithm is not only stable and efficient, but also has improved convergence performance.

Acknowledgments
This research is supported by major project for science and technology of Henan province (No.151100211400)

References
[1] Zhou J L, Deng Y J. (2017) Multi-Mode Traffic Network Path Planning Based on Schedule. Computer system application, 26(12):160-164.
[2] Jalel E, Rafa M. (2011)The urban bus routing problem in the Tunisian case by the hybrid artificial ant colony algorithm. Swarm and Evolutionary Computation, 2(10): 15-24.
[3] SEYED P P, MEHDI M. (2017) A bi-level school bus routing problem with bus stops selection and possibility of demand outsourcing. Applied Soft Computing, 61(12): 222-238.
[4] MA Q L, LIU W N, SUN D H, et al.(2010) Travel route planning model based on the fusion of multi-intelligent computing algorithms[J]. Computer Science,2010, 37(10): 211-214.
[5] MA J, LUO S, Wu L Y, et al. (2017) Research on Highway Passenger Segmentation Based on Canopy-k-means Clustering Algorithm under Parallel Computing Framework. Proceedings of 2017 IEEE International Conference on Smart World, 08: 1596-1601.
[6] YANG Z Z, WANG W D, NOTTEBOOM Theo, et al. (2017) Optimization of terminal network under the door-to-door operation mode of highway passenger transport . Journal of Transportation Engineering, 17(1):119-128.
[7] Ministry of housing and urban rural development of the people's Republic of China. (2008) Economic evaluation methods and parameters of municipal public facilities projects. Beijing: China Planning Press, 178-179.
[8] CHEN Z. (2018) Study on the selection of turn back station of Urban Rail Transit Based on passenger time cost and enterprise operation cost[J]. traffic engineering, 18(2): 24-28.