Optimization of customized bus green line network based on passenger travel time window

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Abstract. In order to solve the problem of public transportation in China, this paper optimizes the customized bus network based on the passenger travel time window and the operating cost. Firstly, the passenger travel time window is proposed, and then a model about the minimum objective of customized bus operation cost, environmental protection cost and passenger travel cost is established, which is solved by lingo software, and then the customized bus route planning is studied according to the case, and finally the conclusion of this paper is drawn.

1. Introduction

With the increasingly serious urban congestion, customized public transport has become an important part of passengers' choice of travel mode. Through the centralized integration of individual travel demand, it provides customized medium and high-end public transport service mode for people with the same or similar travel start and end, travel time and service demand, which has the characteristics of "fixed point, route, car, timing, pricing. At present, relevant scholars have carried out research on the planning of customized bus routes. This paper combines the passenger travel time window and the green line network to transform the passenger travel time loss into time value. Under the constraints of vehicle capacity and passenger travel time window, an optimization model of public transport green line network is established to minimize the passenger travel cost and public transport operation cost, and the optimal driving scheme of public transport is solved by lingo software.

2. Problem description and model hypothesis

2.1. Problem description

The starting and ending points of several passengers are divided into two non overlapping areas. A passenger sends a ride request on the app. If the arrival time of the vehicle meets the time window of the passenger's request to get on the bus and the income requirements of the served passenger's alighting time window and customized bus, the passenger will be served by the vehicle. Then passengers get on at the starting point of the departure area, and are delivered to the destination of the destination area by the customized bus. Each bus can serve multiple destinations, but cannot exceed its maximum capacity. Process of customized bus service for passengers:

(1) Passengers make a ride request on the app;
(2) Judge whether the passenger is in the service scope according to the geographic location information of the passenger;
(3) Judge whether the vehicle meets the passenger time window, whether it will cause income loss
(4) Arrange running vehicles for service;
(5) Customization of candidate vehicles for passengers;
(6) Whether the above judgment meets the conditions;
(7) Customization is successful, new custom vehicles are scheduled for operation.

2.2. Conditional hypothesis
In order to simplify the model, the following assumptions are made for the environment in this paper:
(1) The vehicle is in the ideal condition when driving on the road, namely, there is no congestion;
(2) The vehicle models are unified and the number of people on and off at each station has been determined according to the background operation;
(3) The total number of passengers on board during each bus operation cannot exceed the capacity of the vehicle in a single operation;
(4) Each vehicle can serve multiple stations during the operation process, but each station can only be served once;
(5) Enough vehicles are available to meet the travel needs of the passengers accepted by the road network;
(6) The vehicle is empty when it starts from the parking lot;
(7) Passengers must have corresponding lower station points when they choose to get on the bus station;
(8) The environment of the objective function established in this paper is considered when the public transport has provided services;

The process of public transportation operation is to start from the parking lot and serve passengers in the boarding area until the capacity of the bus reaches the upper limit. The bus then goes to the exit area to send passengers to the stop, and finally returns to the parking lot by empty train.

3. Model building

3.1. Time for passengers to get up and down
The passenger boarding time refers to the sum of the travel time between boarding area stations and the passenger boarding time after the vehicle receives the passenger request.

\[ T_u = \sum_{i=1}^{n} t_j \]

\[ t_j = \frac{d_{\alpha_i i, j}}{v} + \sum_{k=1}^{r} t_{j, k} \]

\[ T_d = \sum_{j=1}^{m} t_j \]

\[ t_j = \frac{d_{\beta_j j, \beta_0}}{v} + \sum_{k=1}^{r_j} t_{j, k, \beta_0} \]

Where: \( T_u \) and \( T_d \) spend the sum of time in the boarding and alighting areas respectively; \( n \) and \( m \) is count the number of upper and lower stations; \( r_j \) is the total number of passengers at a station; \( t_j \) is the sum of time taken for all passengers on site \( i \) and for vehicles from site \( i-1 \) to site \( i \); \( t_j \) is the sum of time spent getting off at Site \( j \) for all passengers and leaving from Site \( j-1 \) to Site \( j \); \( d_{\alpha_i i, j} \) is the distance between site \( i-1 \) and \( i \), \( \alpha_i \) is the parking lot; \( d_{\beta_j j, \beta_0} \) is the distance between site \( j-1 \) and \( j \), \( \beta_0 \) is the last station point; \( v \) for the average speed of vehicles on ideal roads; \( \sum_{k=1}^{r_j} t_{j, k, \beta_0} \) is the sum
of time for all passengers on site \( i \); \( \sum_{k=1}^{n_j} t_{j,k} \) is the sum of time spent by all passengers getting off at
station \( j \).

3.2. Establishment of optimization objective function

The total cost includes passenger cost and bus cost. The purpose of this paper is to minimize the
optimization objective function. The cost of passengers mainly includes the cost of waiting for the bus
and the cost of taking the bus. The cost of public transportation mainly includes the cost of public
transportation operation and the cost of public transportation environmental protection.

(1) Passenger waiting cost \( Z_1 \):

\[
Z_1 = \eta_1 \cdot \sum_{i=1}^{n_i} t_{wi} x_i
\]

(5)

Where: \( Z_1 \) is the cost of waiting for passengers; \( \eta_1 \) is the waiting cost per unit time (yuan / min),
select the average daily wage of urban passengers; \( t_{wi} \) is the average waiting time of passengers at a
station; \( x_i \) is whether the vehicle serves the boarding station;

(2) Passenger Fare \( Z_2 \):

\[
Z_2 = \eta_2 \cdot \sum_{i=1}^{n_i} r_i x_i
\]

(6)

Where: \( Z_2 \) is the passenger's fare; \( \eta_2 \) is the price of a single ride (yuan); \( \sum_{i=1}^{n_i} r_i \) is the total number of
passengers at the boarding station, that is, the total travel demand meeting the service conditions;

(3) Bus operation cost \( Z_3 \):

\[
Z_3 = \eta_3 \cdot (\sum_{i=1}^{n_i} \sum_{j=1}^{n_j} t_{i,j} x_i + \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} t_{i,j} y_j + \sum_{j=1}^{n_j} d_{ij} \beta d_{ij} / \alpha)
\]

(7)

Where: \( Z_3 \) is the operating cost of public transport (mainly including the personnel salary,
management cost, maintenance cost and fuel cost); \( \eta_3 \) is obtained from annual average operating cost /
annual average operating time, unit: yuan / min; \( P \) is the set of customized bus numbers; \( y_i \) is whether
the vehicle serves the next station;

(4) Environmental protection cost of public transport operation \( Z_4 \):

\[
Z_4 = \eta_4 \cdot (\sum_{i=1}^{n_i} \sum_{j=1}^{n_j} t_{i,j} x_i + \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} t_{i,j} y_j + \sum_{j=1}^{n_j} d_{ij} \beta d_{ij} / \alpha)
\]

(8)

Where: \( Z_4 \) is the cost of public transport operation and environmental protection; \( \eta_4 \) is the pollution
cost per unit time (yuan / min), the loss caused by annual average pollution / annual average operation
time of public transport;

To sum up, the optimization model is:

\[
\min Z = Z_1 + Z_2 + Z_3 + Z_4
\]

(9)

\[
\sum_{i=1}^{n_i} t_{i} x_i \leq Q
\]

(10)

\[
d_{q_i,1} \leq 1.5km
\]

(11)

\[
d_{\beta_j,1} \leq 2km
\]

(12)

\[
\sum_{i=1}^{n_i} t_{i,k} \leq 3\text{min}
\]

(13)
\[ \sum_{k=1}^{n} t_{i,k} \leq 3 \text{ min} \quad (14) \]
\[ x_j \in \{0,1\} \quad (15) \]
\[ y_j \in \{0,1\} \quad (16) \]

4. Case Analysis

In this paper, a small-scale example is used to solve the problem. Six boarding points and 10 alighting points in Pengzhou City are selected. The number of boarding and alighting at each station is shown in Table 1. Finally, LINGO software is used to solve the problem.

| Number | Name                                | Number of people |
|--------|-------------------------------------|------------------|
| 1      | Hongyun Star City                   | 76               |
| 2      | DeKun Ting City                     | 52               |
| 3      | Pengcheng Yuanjie                   | 35               |
| 4      | Shengshi Tianpeng                    | 36               |
| 5      | Guose Tianxiang                      | 39               |
| 6      | Shenghuatai                          | 28               |
| 7      | Xu Kang pharmaceutical industry      | 60               |
| 8      | Science and Technology Park          | 31               |
| 9      | Hengli Machinery Factory            | 19               |
| 10     | Ouyidu Furniture Co., Ltd           | 29               |
| 11     | Shuanghu furniture                  | 18               |
| 12     | Power Equipment Co., Ltd            | 32               |
| 13     | Industrial Development Zone          | 27               |
| 14     | Yangjia Food Co., Ltd               | 21               |
| 15     | Yongfa Plastics Co., Ltd            | 18               |
| 16     | Distribution Centre                 | 11               |

The model parameters set in this paper are \( \eta_1 = 0.7 \text{ yuan / min} \), \( \eta_2 = 6 \text{ yuan / person} \), \( \eta_3 = 8 \text{ yuan / min} \), \( \eta_4 = 0.05 \text{ yuan / min} \), \( P = 8 \text{ vehicles} \), \( Q = 35 \text{ people / vehicle} \), \( t_{wl} = 6 \text{ min} \), \( v = 50 \text{ km / h} \).

| Number | Route       | Number of people served |
|--------|-------------|-------------------------|
| 1      | 1-2-6-7-8-9 | 32                      |
| 2      | 1-2-5-11-13-14-16 | 35               |
| 3      | 1-3-6-7-8-13-15-16 | 35               |
| 4      | 2-5-9-12-14-15 | 33                      |
| 5      | 2-4-10-11-13-15 | 33                      |
| 6      | 3-5-8-11-13-16 | 33                      |
| 7      | 3-6-8-10-15   | 32                      |
| 8      | 5-6-12-14-16  | 33                      |

5. Conclusion

On the basis of passenger travel time window, this paper establishes a cost model about customized bus and passengers to plan the route, and finally, it is verified by a case. Customized bus can be regarded as a supplement to bus and taxi, which not only meets the shortage of small one-time capacity of taxi, but also provides a comfortable environment for passengers. In addition, it can not only improve the travel efficiency of passengers, but also make better use of road resources, so customized bus will have a good development prospect in China.
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