Research on new energy electric shared bus route optimization based on floyd algorithm

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Abstract: With the rapid development of cities, the problem of public transport congestion is becoming more and more serious, which affects the commuting punctuality and ride experience of workers. Shared bus has the characteristics of flexible route, comfortable ride and high punctuality rate, and is developing rapidly. In order to save energy and reduce emissions and reduce the impact of vehicles on the urban environment, shared buses are mostly electric buses with new energy sources. As the new energy electric bus is limited by the range and the uncertain demand of shared bus passengers, it is particularly important to plan the driving route in advance. This paper takes typical shared bus routes in LG City as an example, and carries out operation route planning on Visual C++ platform. Plan bus routes according to road conditions and passenger travel needs. The scheme shows that the Floyd algorithm can optimize the shared bus route, ensure sufficient power operation, effectively reduce the company's operating cost, and assist the decision of route scheme. The research results of this paper have practical guiding significance and reference value for the sustainable development of urban commuting in the future.

1. Introduction

With the rapid development of urbanization, the commuting pressure of citizens in big cities increases year by year. The optimization of shared bus routes constructed in this paper dynamically plans driving routes based on the Internet platform and combined with the commuting needs of passengers within the operating range. Fu Zhenhuan combined with the thought of the population weighted opportunity model, proposed the cost weighted opportunity, designed a multi-constraint evolutionary algorithm, took the travel portrait as the input, and gave an efficient shared bus route planning scheme[1]. According to the operation characteristics of shared bus and bus, Yuan Xinling proposed that the coordinated development of the two is conducive to the development of multi-level public transport services, optimize the operation path of shared bus and improve passenger satisfaction[2]. Chen Xi built a customized bus route planning model for commuting with multi-regional operation mode, aiming at minimizing passenger travel costs and vehicle operation costs[3]. A two-stage heuristic algorithm is used to obtain the Pareto solution of the multi-objective optimization model, which provides a basis for customized bus routes. Han Hui studied the cooperative operation mode of shared bus and shared bike, put forward the calculation method of alternative site selection and vehicle pile allocation based on necessity index, and put forward the cooperative operation scheduling and pricing strategy, which provided theoretical support for the construction of cooperative shared transportation system[4].

Some researches on bus route optimization have been made abroad and some progress has been made. The optimization of bus routes in foreign countries mainly utilizes satellite positioning technology...
and relying on the Internet platform to plan the route reasonably in combination with traffic information and passenger travel demand. Lu. Tong collected user information through the Internet to create a planning model aiming at minimizing the number of unreachable passengers, and solved it with Lagrange relaxation algorithm[5].

Domestic and foreign literatures can effectively optimize bus routes, but there are still shortcomings. The existing shared bus operating routes are fixed and cannot be adjusted flexibly according to the needs of passengers, resulting in high operating costs and low travel efficiency. According to the commuting needs of passengers, this paper plans the route of the shared bus, which can reduce the company's operating cost and improve the travel efficiency.

2. Analytical methods

2.1. Basic principle of Floyd algorithm:
Floyd algorithm is an algorithm that uses the idea of dynamic programming to find the shortest path between multiple source points in a given weighted graph. Its goal is to solve the shortest path problem from a single source point to other vertices in a directed graph. As a dynamic programming algorithm, the dense graph has the best effect, and the edge weight can be positive or negative. This algorithm is simple and effective, but the time complexity is relatively high, so it is not suitable for calculating a large amount of data.

Shared bus traffic route network is composed of node set P and operation cost set D between nodes. The formula is expressed as follows:

\[
d_{ij} = \begin{cases} 
\text{transportation cost between } p_i \text{ and } p_j, & \text{if } [p_i, p_j] \in P \\
0, & \text{if } i = j \\
\infty, & \text{if } [p_i, p_j] \notin P
\end{cases}
\]  

(1)

Fig. 1 Driving cost diagram among nodes of a traffic route network

\[
D = \begin{bmatrix}
0 & 29 & 25 & 25 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
29 & 0 & \infty & \infty & 3 & 8 & 12 & \infty & \infty & \infty & \infty \\
25 & \infty & 0 & \infty & 6 & 5 & \infty & 31 & \infty & \infty & \infty \\
25 & \infty & \infty & 0 & 9 & 4 & \infty & \infty & 10 & 48 & \infty \\
\infty & 3 & 6 & 9 & 0 & \infty & 9 & 11 & 13 & 38 & \infty \\
\infty & 8 & 5 & 4 & \infty & 0 & 13 & 10 & 10 & 41 & \infty \\
\infty & 12 & \infty & 9 & 13 & 0 & \infty & \infty & 13 & \infty & \infty \\
\infty & \infty & 31 & \infty & 11 & 10 & \infty & 0 & \infty & 10 & \infty \\
\infty & \infty & \infty & 10 & 13 & 10 & \infty & \infty & 0 & \infty & 11 \\
\infty & \infty & \infty & 48 & 38 & 41 & 13 & 10 & 11 & 0 & \infty \\
\end{bmatrix}
\]  

(2)
2.2. Calculate the lowest cost route

Algorithm steps\(^6\):

1. Input weight matrix \( D^{(0)} = D \);
2. Calculation, \( D^k = (d_{ij}^{(k)})_{n \times n}, \ k = 1,2,3, \ldots, n \) where \( d_{ij}^{(k)} = \min \left\{ d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)} \right\} \)
3. The element \( d_{ij} \) in \( D^n = (d_{ij}^n)_{n \times n} \) is the shortest circuit \( p_i \) to \( p_j \)

Through Floyd algorithm, the lowest cost matrix \( D^{(n)} \) is obtained. On this basis, the path of the lowest cost is backtracked, and the specific path of the lowest cost \( \Gamma_{ij} \) from any node \( p_i \) and node \( p_j \) can be obtained.

### Table 1 Symbol description

| parameter \( d_{ij}^{(0)} \) | The distance between two connected nodes \( p_i \) and \( p_j \) in a regional transportation network |
|-----------------------------|
| \( \Gamma_{ij} \) | Least-cost path |
| \( D^{(n)} \) | Lowest cost matrix |

\[
\begin{bmatrix}
0 & 29 & 25 & 25 & 31 & 29 & 40 & 39 & 35 & 46 \\
29 & 0 & 9 & 12 & 3 & 8 & 12 & 14 & 16 & 24 \\
25 & 9 & 0 & 9 & 6 & 5 & 15 & 15 & 15 & 25 \\
25 & 12 & 9 & 0 & 9 & 4 & 17 & 14 & 10 & 21 \\
31 & 3 & 6 & 9 & 0 & 11 & 9 & 11 & 13 & 21 \\
29 & 8 & 5 & 4 & 11 & 0 & 13 & 10 & 10 & 20 \\
40 & 12 & 15 & 17 & 9 & 13 & 0 & 20 & 22 & 13 \\
39 & 14 & 15 & 14 & 11 & 10 & 20 & 0 & 20 & 10 \\
35 & 16 & 15 & 10 & 13 & 10 & 22 & 20 & 0 & 11 \\
46 & 24 & 25 & 21 & 21 & 20 & 13 & 10 & 11 & 0 \\
\end{bmatrix}
\]

(3)

\[
\begin{bmatrix}
0 & 1 & 2 & 3 & 2 & 3 & 2 & 3 & 3 & 3 \\
0 & 1 & 4 & 4 & 4 & 5 & 6 & 4 & 4 & 4 \\
0 & 4 & 2 & 5 & 4 & 5 & 4 & 5 & 5 & 5 \\
0 & 4 & 5 & 3 & 4 & 5 & 5 & 5 & 8 & 8 \\
2 & 1 & 2 & 3 & 4 & 1 & 6 & 7 & 8 & 7 \\
3 & 1 & 2 & 3 & 1 & 5 & 6 & 7 & 8 & 7 \\
4 & 1 & 4 & 5 & 4 & 5 & 6 & 4 & 4 & 9 \\
5 & 4 & 5 & 5 & 4 & 5 & 4 & 7 & 5 & 9 \\
3 & 4 & 5 & 3 & 4 & 5 & 4 & 5 & 8 & 9 \\
8 & 7 & 7 & 8 & 7 & 7 & 6 & 7 & 8 & 9 \\
\end{bmatrix}
\]

(4)

From the output matrix \( D^{(n)} \) and \( \Gamma_{ij} \), the minimum operating cost and the path of the minimum operating cost at any point can be obtained. For example, the minimum operating cost from S to T is 46 yuan, and the path of the minimum operating cost is S→A3→C3→T.

3. Case analysis

This paper takes typical routes of a shared bus company in LG City as an example. The shared bus company operates three fixed routes, with three buses leaving at 7:00 am on the same route. The bus carries 48 passengers, has a range of 150km and a battery capacity of 167.54kWh. The company has formulated the operating rules: the bus carrying capacity should be less than 48 people and the driving time should be less than 1h, so three buses should be guaranteed to pass through all stations in the area.

According to the company's long-term statistics, the average cost and duration of the road section within the operation scope are as follows:
Fig. 2 Operation route topology diagram

Table 2 Fixed operation route table

| Route number  | Way to site | route                  | path length | cost   | time  |
|---------------|-------------|------------------------|-------------|--------|-------|
| Original route 1 | A1, C1     | S - A1 - C1 - T        | 61km        | 54 yuan| 53min |
| Original route 2 | A2, B1, C2 | S - A2 - B1 - C2 - T  | 65km        | 52 yuan| 60min |
| Original route 3 | A3, B2, C3 | S - A3 - B2 - C3 - T  | 64km        | 50 yuan| 64min |

4. Conclusions and discussion

4.1. Optimized route for single bus
When there are passengers at a station within the operating area of shared bus in LG City, the optimal route of buses passing through this point can be calculated according to the existing traffic cost data. By calculating the optimal driving routes of all stations in the operating area, the traffic cost can be reduced and the operating efficiency can be improved.

The results are shown in the chart below:

Fig. 3 Route optimization topology diagram
Table 3 Route optimization table

| Route number | Way to site   | The path                      | path length | cost | time |
|--------------|--------------|------------------------------|-------------|------|------|
| Line 1       | A1, B1, C2   | S - A1-B1 - C2 - T           | 63km        | 53 yuan | 59min |
| Line 2       | A2, B2, C2   | S - A2- B2- C2 - T           | 63km        | 50 yuan | 60min |
| Line 3       | A3, C3       | S - A3 - C3 - T              | 59km        | 46 yuan | 51min |
| Line 4       | A2, B1, C2   | S - A2 - B1 - C2 - T         | 65km        | 52 yuan | 60min |
| Line 5       | A3, B2, C2   | S - A3 - B2- C2- T           | 64km        | 49 yuan | 60min |
| Line 6       | A1, C1       | S - A1 - C1 - T              | 61km        | 54 yuan | 53min |

According to the characteristics of new energy electric shared bus and combined with the operating scope of shared bus in LG City, several routes suitable for bus operation have been planned, including the route with the lowest operating cost, the route with the shortest operating time, the route with the lowest guaranteed electric quantity and the route with the maximum electric quantity.

4.2. Coordinated route scheduling by multiple buses

4.2.1. Basic features

The departure time of conventional shared bus is fixed, the operation route is fixed and the stop station is fixed. Its features mainly include: (1) to meet the commuting needs of urban residents; (2) to meet the requirements of high station density; (3) to operate only two trains in the morning and evening peak hours.

The collaborative operation routes of shared buses are determined by the needs of passengers. Based on the needs of passengers, this study optimizes the operating routes of the shared bus to reduce the operating costs and the commuting time of passengers.

4.2.2. Scheduling rules

Passengers can book a trip through the operator's mobile app by submitting information such as boarding stations and time Windows for receiving services. After receiving the information, the bus company will judge whether to respond according to its own operation ability, and give the final result back to the passengers. If the bus company does not respond, passengers will be advised to take other means of transport.

There are altogether 3 shared buses in LG City. Before the trip, according to the travel information of passengers, the operation routes are reasonably arranged to minimize the overall cost and improve the operation efficiency.

4.2.3. Principle of cooperative bus scheduling

There are a total of 8 stations in LG City's shared bus operating area. During the morning and evening rush hours, the number and location of passengers on the platform are random and uncertain. Grouping the features of platforms with passengers,
Fig. 5 Venn diagram of 6 bus routes

Table 4 Site portfolio summary

| Type            | Site combination                                                                 |
|-----------------|----------------------------------------------------------------------------------|
| A single platform | {A1} {A2} {A3} {B1} {B2} {C1} {C2} {C3}                                          |
| Two platform     | {A1, C1} {A1, B1} {A1, C2} {A2, B1} {A2, B2} {A2, C2} {A3, C3} {A3, B2} {A3, C2} {B1, C2} |
| Three platform   | {A1, B1, C2} {A2, B2, C2} {A2, B1, C2} {A3, B2, C2}                              |

When there are more than three platforms in the operation scope, the cooperative scheduling routes of multiple buses can be obtained by optimizing the combination of additional routes according to the above table. Reduce operating costs and improve operating efficiency for shared bus companies.

![Graph showing passenger flow](image)

Table 5 Compare the two schemes

| Course name | The original route | Adjusted Route (Morning Peak) | Adjusted Route (Evening Peak) |
|-------------|--------------------|--------------------------------|-------------------------------|
| The path    | Original route 1: S-A1-C1-T | Line 2: S-A2-B2-C2-T | Line 1: S-A1-B1-C2-T |
|             | Original route 2: S-A2-B2-C2-T | Line 3: S-A3-C3-T  | Line 2: S-A2-B2-C2-T |
|             | Original route 3: S-A3-B2-C3-T | Line 6: S-A1-C1-T  | Line 5: S-A3-B2-C2-T |
| total cost  | 312 yuan           | 302 yuan                   |                               |
| total distance | 380 km            | 373 km                     |                               |
| total time  | 354min             | 343min                     |                               |

5. Conclusions

Visual C++ was used to plan the shared bus route. Based on Floyd algorithm, the experimental scheme was analyzed with the road working condition data of LG City, and the bus route was optimized. The
results show that Floyd algorithm is convenient and efficient for the optimization of bus route scheme, which can effectively reduce the company's operating cost and improve its competitiveness. The current research of this paper is mainly aimed at the optimization of three fixed routes in a certain area, and the optimization of bus routes with more routes and more stations is worthy of further study.

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