

# *Study on Path Planning of Urban Sharing-bike Connecting Rail Transit*

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**Abstract:** Sharing-bikes are characterized by health, greenness and environmental protection, effectively solving the "last kilometer" problem. It is of great significance to reasonably plan the sharing-bike connecting rail transit routes to meet the traveler's needs, build safe urban traffic travel environment, and guide bicycle travel. Based on the shared bicycle trip data, this paper proposes an optimal paved lane path planning model for a sharing-bike connected rail transit based on traffic network. Based on spatial clustering and improved Dijkstra's algorithm, the steps and principles for solving the model are given. The results of the example of Beijing No. 2 Line as a planning example show that this model has the characteristics of convenience of route layout and deployment cost, and has certain feasibility, which enriches the path planning method of bicycle lanes.

## 1. Introduction

In order to solve urban congestion, bicycles have the advantages of healthy, non-polluting, and small road rights. They have received support and advocacy from various governments [1]. The launch of shared bicycles has been highly praised by travelers. According to statistics, the use of shared bicycles for rail transit during peak periods in Beijing accounted for 46% of the total number of rides, which solved the daily "last kilometer" travel problem and met commuting and leisure requirements. , connection and other travel needs. However, due to the backward facilities and poor management of China's roads on the construction of bicycle lanes, the development of shared bicycles is restricted. For example, many roads have no single lanes and non-standard single lanes, as shown in Figure 1. Therefore, it is worth studying how to guide people to use bicycles better. There are few researches on sharing bike guidance and transportation planning<sup>[2,3]</sup>. Only the method of JieBao et al. in path planning proposes a method of using greedy algorithm to plan bicycle lanes based on sharing bicycle cycling trajectories<sup>[2]</sup>. There are many researches on path planning. Huang Min et al., based on the topological expression of road network, established the planning and research on the guidance path of the guiding signs of interest points<sup>[4]</sup>; Song Qing et al. also proposed the construction method of urban bicycle network based on Open Street Map, and based on it. Criterion Bicycle path optimization method<sup>[5]</sup>.



No Bicycle Lanes    Non-standard Bicycle Lanes    Standard Bicycle lanes

Figure 1 Bicycle Lane

In this context, the purpose of this paper is to construct a path planning model for the shared car connecting track channel. First of all, according to the structure of the traffic network, the optimal lane paving path model for bicycle link rail transit planning and sharing is established. The route planning model from the starting point to the orbital site, combined with spatial clustering and the improved Dijkstra algorithm, gives the steps and principles of the model solution. Finally, the Beijing Metro Line 2 area is taken as an example for planning.

## 2. Research Methods

### 2.1 Research Ideas and Modeling

For the traffic network and orbital sites in a given area, a number of single-vehicle lane paving paths are planned with the user's concentration point as the starting point and the track site as the defect point. This route mainly considers three criteria, namely, starting point, riding comfort, and construction cost, so as to plan a route with high service efficiency and easier and faster cycling.

#### 2.1.1 Traffic Network Modeling

Traffic network modeling is the basis of the entire path planning. Model the traffic network in the planning area as a directed network diagram:  $G = (V, S, A)$ . Among them:  $V = \{v_i\}$ , a collection of all nodes (crossroads) on the road network;  $S = \{s_j\}$ , rail transit site collection;  $A = \{a_{ij} = \langle v_i, v_j \rangle, b_{ij} = \langle v_i, s_j \rangle | v_i, v_j \in V, s_j \in S\}$ , directed arc segment collection,  $a_{ij}, b_{ij}$  represents directed arcs from nodes to and to sites.

The road network in actual traffic still has problems such as the direction of the road section and the existence of orbital sites on the road section. Therefore, the nodes  $V$  and  $A$  of the road network have several attributes, including the north deviation angle  $\theta(v_i)$  and the logical connectivity between adjacent nodes. The north deviation angle refers to the clockwise angle from the north direction to the arc section. The angle is determined by the actual situation.

#### 2.1.2 Optimization Criteria

##### 1) Origin-Destination Judgment

The origin-destination is an important indicator when planning a route. In order to ensure that the laid single lanes serve more people, the origin (E) should be determined near the residence, work, and shopping malls. Measured by the user clustering degree  $Q(p, r) = \left\{ \frac{p_i}{r_i} \right\}$ , it means that within a

planned path, it is divided into several cells, and the area with the largest ratio of users to the area of the cell is selected as the origin. According to the research background, the destination (F) is a number of orbital sites within the planning area. The origin-destination judgment is:

$$c_1(e, f) = \begin{cases} E = \{e_i | e_i = \max Q(p_i, r_i)\} \\ F = \{f_i | f_i \in S\} \end{cases} \quad (1)$$

### 2) Riding Comfort

Riding comfort is mainly reflected in road traffic conditions and road flatness (uphill and downhill) experience. Riding comfort is described by the coefficient  $c_2(m, m')$ , where  $m$  is the road traffic volume, and the smaller the value, the more comfortable;  $m'$  is the road road flatness factor, and the closer to 0, the flatter. The degree of riding is:

$$c_2(m, n) = \min\{m_i, m'_i\} \quad (2)$$

### 3) Construction Cost Criteria

The construction cost mainly considers two factors, the length of the constructed road section and the difficulty level of different road grades, and the length of the road section from which the pick-up point is located is also one of the important criteria for user travel selection. Assuming that the basic unit construction cost is  $c_x$ , and the weighted coefficient of difficulty for the expressway, main road, secondary road, and branch road is  $\mu = \{\mu_1, \mu_2, \mu_3, \mu_4\}$ , the construction cost is the product of the weighting coefficient and the length of different grades of road segments and  $c_x$ . The construction cost criteria are:

$$c_3 = \sum \mu a_{ij} c_x \quad (3)$$

In summary, the optimization goal is to minimize the convenience and total cost of constructing several connection routes within a given area.

## 2.2 Planning Steps and Algorithm Design

For the solution of this model, the K-means spatial clustering algorithm is used to obtain the planning origin first, and then an improved Dijkstra algorithm is used for path search.

### 2.2.1 Determining Planning Area and Preprocessing

The pre-processing is mainly to solve the problem of planning several routes within the pre-planning area, which is closely related to the riding characteristics of the users of shared bicycles. According to the report of ofo, the average time of riding a user is 9 (winter)/10 (summer) minutes, and 62.4% of the users ride within 0.5-2KM. Assuming that the planning area is rectangular, its length and width are respectively, and the service scope of each planning path is  $l$   $\text{KM}^2$ . The total planned number of lanes in the planning area is:

$$n = \frac{L_1 + L_2}{l}, l = L_1 \times L_2 \quad (4)$$

### 2.2.2 User Space Clustering Algorithm

The K-means algorithm is an iterative process that minimizes the sum of squared distances between all samples in the clustering domain and the cluster center. This paper mainly uses this to find the starting point of the route. To facilitate the implementation of the algorithm, the following variables are defined: At a certain moment in the planning area, the set  $\sigma$  of all shared bicycle positions is  $w = \{w_\sigma\}$ , and each bicycle has a latitude and longitude attribute  $w_\sigma = (o_\sigma, o_\sigma)$ . The number

of clusters is  $n$  calculated by equation (4), initial cluster center  $\{w_n\}$ . The Euler distance  $k = \sqrt{(w_\sigma - w_n)^2}$  is selected as the clustering basis, and the evaluation criterion is the error square sum criterion  $J$ . Specific steps are as follows:

$$J = \sum_{\sigma=1}^{\sigma} \sum_{w \in W} k^2 \quad (5)$$

Step 1 Select any  $n$  object from the bicycle position set  $W$  as the initial cluster center of each cluster.

Step 2 For each object  $w \in W$ , calculate the distance  $k$  of the centers of the remaining clusters and assign them to the cluster with the smallest  $k$ .

Step 3 Update the cluster center  $\{w'_n\}$ .

Step 4 Calculate the standard measure  $J$  according to equation (5). If the difference between two iterations of  $J$  is less than the given value, terminate the algorithm. Otherwise, repeat step 2.

### 2.2.3 Improved Dijkstra Path Search Algorithm

In order to ensure that cyclists connect the rail traffic faster, the nearest track site must be found around the starting point. Therefore, route planning becomes the problem of searching for the shortest route between start and end points. Although Dijkstra's algorithm is typical for finding the shortest path algorithm in the weighted network graph<sup>[7-8]</sup>, it has low efficiency and needs to fully know the starting point and the end point. However, the traffic network has a number of traffic constraints and cannot be simply abstracted into a directed network with non-negative weights. Therefore, the Dijkstra algorithm must be appropriately modified. In order to find out the route end point, the shortest route, and solve the traffic constraint problem of different road grades more efficiently, the algorithm idea: ①. Weight the different road grades in the road network; ②. Calculate the starting point to the service scope of each planned route. The shortest path of each orbital site in this range avoids unnecessary double counting; ③. Select the minimum value in ② as the result. Specific steps are as follows:

Step 1: Evaluate the difficulty coefficient  $\mu = \{\mu_1, \mu_2, \mu_3, \mu_4\}$  and the road flatness  $\{m'\}$  for different road classes in the traffic network map.

Step 2: Take  $n = 1$  to calculate the value of  $w'_1$  to a number of orbital sites  $\{z_1\}$  in the service area.

Step 3: Select  $z'_1 = \min\{z_1\}$  to keep track of the route and site.

Step 4: Let  $n = \{1, 2, \dots, n\}$  be respectively repeated steps 2 and 3 until the search for the route is complete.

## 3. Application

Taking the area in Beijing Metro Line 2 as a planning example, several lane lanes in the area are planned using the model proposed in this study, and compared with the planning results that do not consider the tangible coefficient, to verify the feasibility of the proposed method.

According to the actual situation in the planning area and comprehensive consideration of the current facilities in the road network, since Beijing is a plain city and an atypical mountainous city, the road flatness is uniformly taken as 0, and the parameter values in the algorithm are shown in Table 1.1 manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the

book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. As show in Fig. 1 and Table 1, three scheme comparing.

Based on the above parameters, and combined with the actual road data in the road network, 12 models of 12 paths are planned within the area using the model proposed in this study. Based on the daytime and nighttime data provided by ofo on a working day in 2017, taking into account the difference between the user's work area and residential area, a user space clustering algorithm was applied to determine the starting point of 12 plans. According to the optimization criteria, and according to equation (4,5) and improved Dijkstra path search algorithm, the planned path is shown in Figure 2.

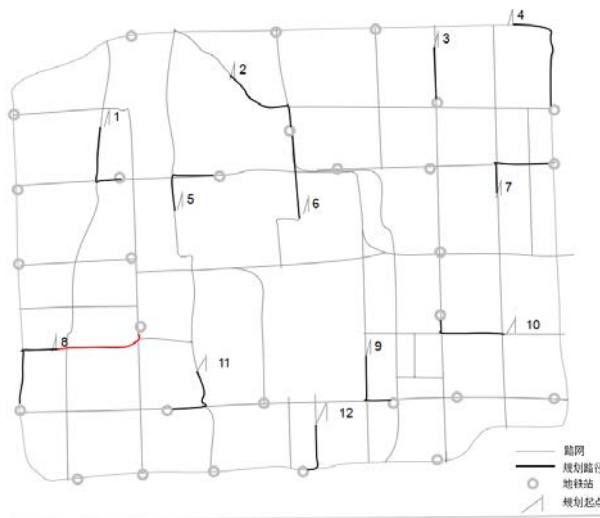


Figure 2. Two or more references.

The red line in Figure 2 is the result of the planned route without considering the difficulty of different grades of roads (the rest of the results are consistent and not marked). It can be seen that although there is a certain advantage in terms of distance without considering the weighting, the overall consideration of the needs of the traveler and the laying cost is not dominant. The length of the planning path is 1.0-1.5KM, which is the average distance of bicycle travel. It can be seen that the calculation results of the planning model proposed in this study can be used as a reference for solving the urban road bicycle planning, and can better meet the requirements of the bicycle traveler as a whole. Traffic managers' needs.

Table 1. Parameters Table

Single path service range(KM <sup>2</sup> )	Planning area length(KM)	Planning area width(KM)	Construction easing coefficient $\mu$	Pavement flatness factor
1	4	3	{1,1.05,1.1,1.15}	{0}

#### 4. Conclusion

This paper takes the optimal construction route model of planning and sharing-bikes connecting rail transit as the research objective, and establishes the path planning model from the origin to the orbital site based on the optimization criteria of the origin-destination, riding comfort and construction difficulty cost. An algorithm for solving the model is designed. Firstly, the planning

area is preprocessed. Then use the spatial clustering algorithm to determine the planning origin based on the sharing-bikes position data. Finally, the improved Dijkstra algorithm is used to determine the destination and path. Taking the Beijing No. 2 subway line area as an example for planning, and comparing it with the plan that does not consider the tangible coefficient, it shows that this study is feasible. This article has certain reference value for alleviating urban congestion, promoting bicycle travel, and improving bicycling services. As this study only collects data on one kind of sharing-bikes, more data will be collected in the later research and more optimization criteria will be considered.

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