

Study on the installation of bus lane entrances at signal intersections

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Abstract. This article analyzes the feasibility of setting up bus lanes at intersections. Firstly, a multi-objective optimization model for signal control is established. Vissim simulation software is used to output delay data for different types of vehicles at intersections, and the feasibility of bus lanes at intersections is analyzed. The results show that setting bus lanes can improve bus speed and shorten travel time to a certain extent. The calculation results of the theoretical model can provide a reference for parameter calibration of the simulation model, and the simulation results can be compared and analyzed with the calculation results of the theoretical model to verify the effectiveness of the theoretical model and ensure the accuracy of the final benefit evaluation results. Provide theoretical reference for the setting of bus lanes.

Keywords: Bus lane, signalized intersection, Vissim, simulation analysis

1. Introduction

In recent years, due to factors such as the further acceleration of urbanization, the sharp increase in the number of private motor vehicles, and the limited development of urban public transportation systems, traffic congestion has occurred on urban roads, and prominent urban transportation problems have restricted urban economic development. Therefore, implementing the public transportation priority development strategy has become one of the important strategies to solve urban transportation development problems^[1]. The establishment of bus lanes can ensure the exclusive right of way for public transportation, improve the reliability and independence of public transportation, and reflect the concept of public transportation priority. Many scholars at home and abroad have conducted research on bus lane layout methods, and the existing research results can be divided into two categories: 1) micro simulation; 2) Macroscopic network optimization.

Lo et al. studied network planning issues based on time dimensions with the goal of maximizing consumer surplus. Design decisions include road pricing, lane widening, and so on^[2-3]. J. Boffie et al. further considered issues such as the impact of land economic benefits on discrete road network design based on time dimensions^[4]. Wang Weiqi uses the fuzzy comprehensive evaluation method to coordinate the planning and layout of bus lanes on the overall surface of the urban spatial structure, urban overall planning, and socio-economic development^[5]. In order to improve the efficiency of the overall transportation network after the establishment of bus lanes, Ma Meina conducted a study on the optimization of the layout of bus lanes in the transportation network through random user equilibrium under multimodal transportation modes, reducing the per capita travel time and average saturation in the network by 23.18% and 15.52%, respectively^[6].

2. Setting method of bus lanes at intersections

The setting and operation of the intersection entrance lane has an important impact on the intersection traffic operation efficiency. The purpose of implementing bus priority at intersections is to reduce delays at bus intersections. The bus lanes at intersections can be set up in the following ways: feedback line, through, staggered, and zigzag dedicated entrance lanes. The specific analysis is as follows.

1) *ayout form of through-type bus entrance lane*

A through bus lane refers to a parking line extending the bus lane on a road section to the entrance lane, which is exclusively used by bus vehicles and not allowed by social vehicles, effectively ensuring the continuity of the bus lane. But when the bus lane is set on the roadside, a borrow area needs to be set up on the bus lane before the entrance of the intersection, for social vehicles with a right turn demand to change lanes, as shown in Figure 1.

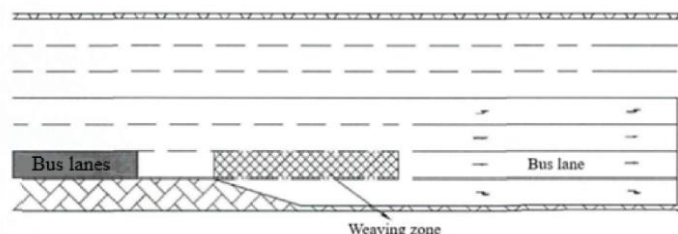


Figure 1. aout of Through Bus Dedicated Entrance Lane

The layout of through bus dedicated entrance lanes can effectively ensure the priority of buses at intersections, greatly reducing bus delays, and in practical applications, further improving bus service levels through the establishment of bus dedicated phases. However, due to the fact that the through bus lane occupies an entrance lane resource at the intersection, it can lead to increased delays in social vehicles.

2) *Layout form of staggered bus dedicated entrance lane*

Staggered bus lanes are designed to adjust the location of the entrance lane on the basis of the straight through type. When deployed, the intersection bus lanes and the section bus lanes are staggered by one lane to provide more space for turning traffic. Under this layout, there will be a bidirectional interweaving of bus vehicles and right-turning vehicles, which has a negative impact on the traffic efficiency of the entrance. Staggered layout forms are mostly suitable for situations where the flow of steering vehicles is large, as shown in Figure 2.

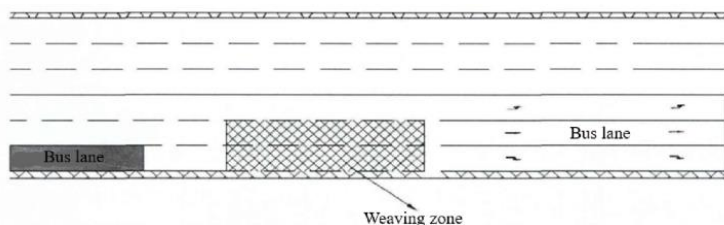


Figure 2. Layout of Staggered Bus Dedicated Entrance Lanes

3) *Layout form of feedback line bus entrance lane*

The feedback line bus entrance lane refers to setting the feedback line near the intersection of the bus lane, allowing only right-turning social vehicles to enter the bus lane through the feedback line, and sharing the entrance lane with bus vehicles. Under this deployment scheme, there is mixed traffic interference between right-turning vehicles and public transport vehicles. At the same time, when there are public transport vehicles waiting for a signal in front of the right-turning vehicles, social vehicles can only queue up in the rear, which to some extent increases the delay of right-turning social vehicles, so it has certain limitations in practical application, as shown in Figure 3.

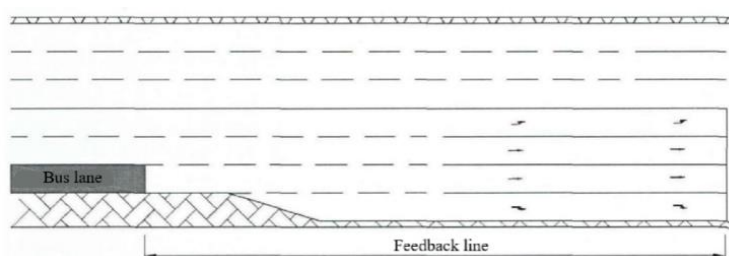


Figure 3. Layout of bus entrance lanes with feedback lines

3. Establish an evaluation index model

In order to better connect the model with the current situation of urban traffic, make the research results more accurate, and make the case analysis more consistent with the actual situation, the following assumptions need to be made about the basic situation in the model:

- 1) *Only study the impact of bus lane settings on intersection delays*
- 2) *The setting of bus lanes does not affect the choice of residents' travel modes, and the bus passenger flow remains unchanged*
- 3) *The bus departure frequency remains unchanged.*

To reflect the impact of bus lane settings on traffic conditions, this paper establishes a multi-objective optimization model to achieve maximum traffic efficiency and minimum delay time at intersections. Analyze and evaluate the setting of bus lanes based on conditions such as road capacity, traffic flow speed, vehicle delay, and intersection traffic efficiency.

3.1. Road capacity

Actual capacity refers to the maximum traffic flow that can be passed per lane per unit time under actual road traffic conditions. Considering traffic conditions, environment, and other factors, actual capacity is a reduction in theoretical capacity. Road capacity is an important component of road saturation calculation, and the calculation formula is:

$$C_i = \sigma * C_0 * C_1 * C_x \quad (1)$$

Where C_i is capacity; C_0 is the theoretical traffic capacity of the standard lane (unit: pcu/h); C_1 is the lane reduction coefficient; C_x is the lane width reduction coefficient, which is the parameter value of other influencing factors.

3.2. Traffic flow speed before setting bus lane

The average speed V_C of social vehicles during mixed driving is:

$$V_C = V_{C0}(-0.3610 * Q/C + 1.0205) \quad (2)$$

Where, Q is the actual traffic flow of the road section (unit: pcu/h), and C is the traffic capacity of the road section (unit: pcu/h).

The average travel speed V_B of public transport vehicles when driving mixed is:

$$V_B = V_{B0}(-0.229 * Q/C + 1.0037) \quad (3)$$

Among them, V_{C0} is the free flow rate of social vehicles on the road section (unit: km/h).

3.3. Traffic flow speed after setting bus lane

The speed of social vehicles is:

$$V_C = \begin{cases} V_{C0}(0.3747 \frac{Q_C}{C_C} + 1.0803), S_b \leq 0.3 \\ V_{C0}(-0.3718 \frac{Q_C}{C_C} - 0.0931 \frac{Q_B}{C_B} + 1.0928), S_b > 0.3 \end{cases} \quad (4)$$

Where, Q_C is the hourly traffic volume of social vehicles (unit: pcu/h); Q_B is the hourly traffic volume of public transport vehicles (unit: pcu/h); Q_C is the actual traffic capacity of the social lane (unit: pcu/h); C_B is the actual capacity of the bus lane (unit: pcu/h); S is the saturation of the bus lane. The speed of the bus is the speed of the bus.

$$V_B = \begin{cases} V_{B0}(-0.2068 \frac{Q_B}{C_B} + 1.0659), S_b \leq 0.5 \\ V_{B0}(-0.2054 \frac{Q_B}{C_B} - 0.08332 \frac{Q_C}{C_C} + 1.10668), S_b > 0.5 \end{cases} \quad (5)$$

3.4. Total vehicle delay

The average delay d of vehicles at signalized intersections is:

$$d = \frac{c(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} - k \left(\frac{c}{q^2} \right)^{\frac{1}{3}} x^{(2+5x)} \quad (6)$$

Where c is the total cycle of intersection signal timing (unit: s); λ Is the ratio of the effective green light time to the cycle length; Q is the actual crossing amount (unit: pcu/h); X is the road saturation.

4. Example analysis

4.1. Current situation of roads

At the intersection of Dangre Road and Sela Road in Chengguan District, Lhasa City, Dangre Road is a planned urban trunk road, and Sela Road is a planned urban secondary trunk road. There is no bus lane built. Dangre Road runs east west, with 2 lanes at the east entrance, 4 lanes at the west entrance, Sela Road runs north south, and two-way 6 lanes at the south entrance. The intersection adopts four phase control, with a cycle of 149 seconds, a total delay of 2550 vehicles per second, and an average parking delay of 20.56 seconds.

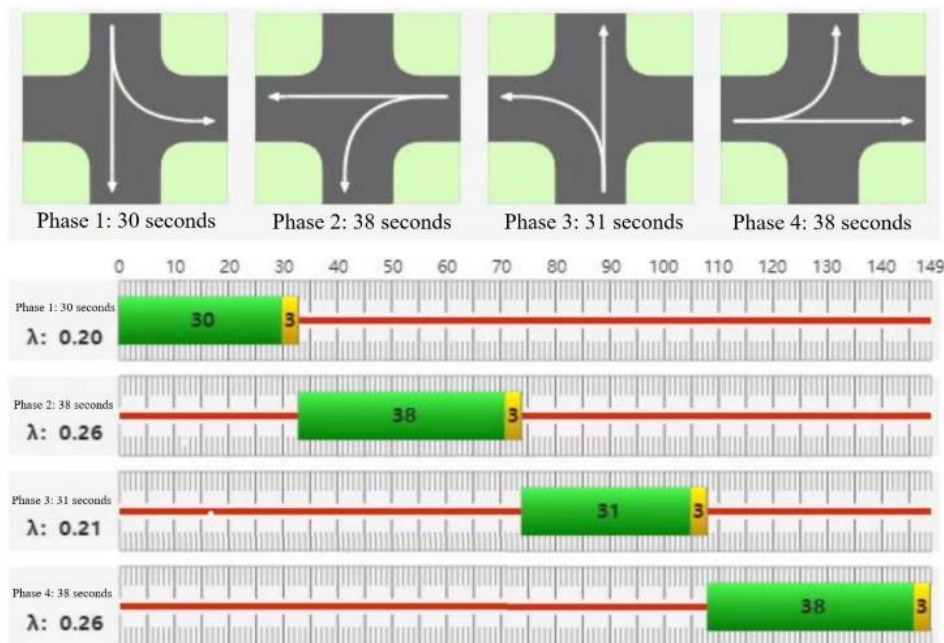


Figure 4. Signal Timing Phase Diagram

4.2. Current situation of intersection delay

During peak hours, under the current signal timing and traffic management conditions, the actual capacity of the intersection is 3836 pcu/h. The design capacity of each entrance can be calculated as shown in Table 1. The design capacity of the intersection is $C=707+707+440+440=2294$ pcu/h. Therefore, the above design capacity is significantly different from the actual capacity, with an imbalance coefficient of 1.4. Figures and Tables.

Table 1. Design capacity of each entrance

	Design capacity	Peak hour traffic flow
West inlet	707	1145
East inlet	707	1507
South inlet	440	1041
North Entrance	440	866

4.3. Vissim simulation results

Set bus lanes on the road, using the average queue length, maximum queue length, and the number of stops in the queue as evaluation criteria, and use vissim software to simulate. Based on the simulation, the total delay at the intersection is shown in Figure 5.

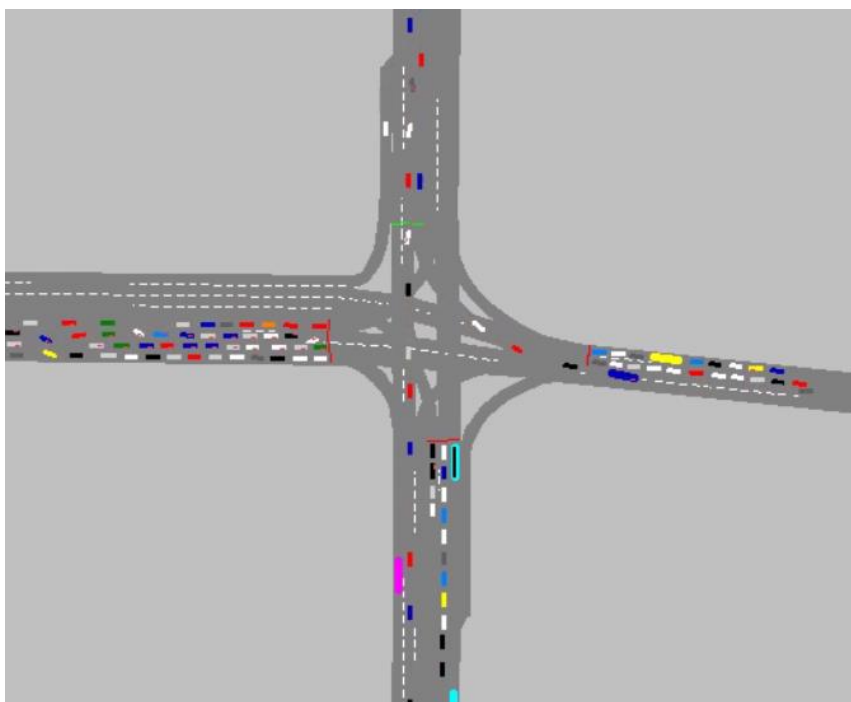


Figure 5. Simulation operation diagram

The survey data and calculation data can be used to obtain the values of various indicators of the road, and the survey data and calculation data can be used to obtain the values of various indicators of the road. In addition, the simulation model also strengthens the consideration of the road traffic conditions, environmental conditions and regional particularity, improves the simulation environment of the model, and reduces the model error. According to the calculation results provided by the mathematical model, such as the average time consumption of road network people and the delay of road vehicles, Adjust the default values of parameters such as the number of passengers and vehicle acceleration and deceleration in the simulation model to make it more consistent with the actual situation of the road network.

It is verified that the parameters of the road optimization model are consistent with the actual situation of the region. Therefore, based on the road optimization model, the benefit evaluation of the bus lane set on the road is carried out. See Table 2 for the details of the evaluation, which improves the traffic efficiency of social vehicles. The travel time of social vehicles is reduced, and the driving speed is increased. For the entire road network, the total consumption time and vehicle delay of the road network are reduced.

Table 2. Comparison of simulation results based on vissim

Before setting				
Entrance lane	Average queue length	Maximum queue length	Number of stops in queue	Average vehicle delay
West inlet	74.67	218.58	57.93	52.34
East inlet	41.88	135.43	36.51	31.69
South inlet	43.26	144.45	54.40	48.19
North Entrance	30.34	119.41	45.59	39.89
After setting				
Entrance lane	Average queue length	Maximum queue length	Number of stops in queue	Average vehicle delay
West inlet	63.76	143.62	37.59	37.48
East inlet	35.33	120.57	36.47	29.45
South inlet	31.29	114.28	40.13	35.19
North Entrance	25.41	107.51	37.64	32.66

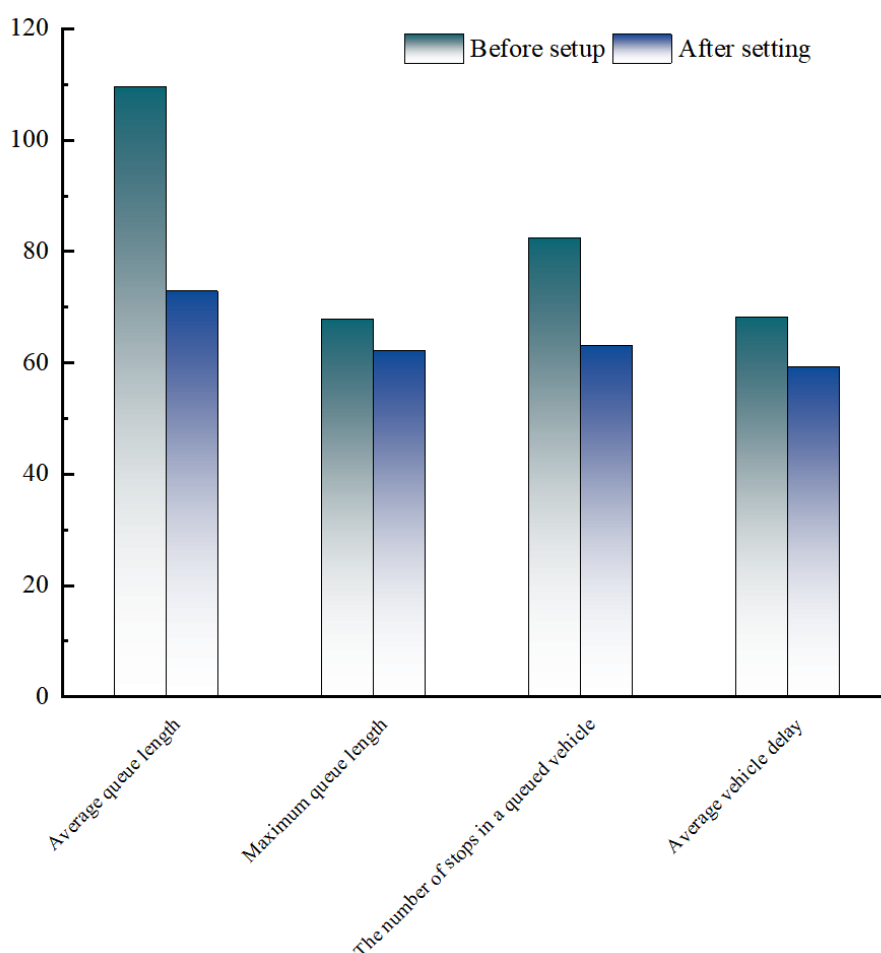


Figure 6. Result Comparison Analysis Chart

Therefore, the following three points can be learned:

- 1) Based on the existing road and traffic conditions of the road, setting up a bus lane in this section can improve bus speed to a certain extent and shorten travel time;
- 2) The evaluation result is based on the comprehensive analysis of the parameters of the optimization model and the actual collected data, and the reliability of the evaluation result is high;
- 3) The analysis results of the two evaluation methods are within the allowable error range, verifying the accuracy of the model, which conforms to the traffic characteristics of the region.

5. Conclusions

This paper proposes a method that combines mathematical models with simulation models. Taking the intersection of Dangre Road and Sela Road in Chengguan District of Lhasa City as an example, the applicability of bus lane settings is analyzed by comparing the queue length and vehicle delays at the intersection before and after bus lane settings. It also introduces the setting methods of bus lanes at intersections, selects lateral bus lanes as the research object, compares the applicable conditions of various forms of bus lanes, and draws a conclusion that feedback line intersections are suitable for the current situation of roads in Lhasa. Combining mathematical models with simulation models for the evaluation of the benefits of setting up bus lanes, the data can support each other. Taking the intersection of Dangre Road and Sera Road in Chengguan District of Lhasa City as a case study, through comparative analysis, setting up bus lanes can greatly improve road traffic efficiency.

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