Research on Bus Station Setting of Adjacent Signalized Intersection Based on Vissim

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Abstract. In order to improve the capacity of intersections, this paper discusses the impact mechanism of bus stations on vehicle delays at the upstream and downstream of adjacent intersections. Using VISSIM simulation software and taking two-way six lanes as the main line for simulation, it can be obtained that the greater the distance between the platform and the stop line, the smaller the average delay of vehicles; The lower the traffic volume is, the less the delay per bus is, and the recommended position of bus platform under different traffic volume is given according to the delay curve; taking Xuzhou mining university station as an example, this paper compares the vehicle delay between the recommended location and the existing location, and verifies the effectiveness of the recommended location of the bus station at the adjacent signal intersection.

1. Introduction
With the development of public transport in China, public transport has become the choice of most people. However, its docking relies on bus stations. The setting of bus stations should ensure the safety of bus passengers waiting for the bus, facilitate passengers to transfer and cross the street, facilitate bus stops and smooth access, and minimize the impact on the traffic capacity of sections and intersections [1].

In terms of research on bus station setting, Yang et al.[2] established the total passenger delay model of the intersection under the condition of two-phase signal control intersection with no bus lane, and established the signal optimization model based on the principle of minimum total passenger delay. According to the relationship between the best red light time, bus arrival time, stop service loss time and green light loss time, the best distance between bus stop station and stop line at signalized intersection is obtained. Wang. [3] adopted the analytic hierarchy process (AHP) to select appropriate evaluation indexes for three bus stop setting methods at signalized intersections, and quantitatively compared the three setting methods to provide guidance for new bus stop setting at urban signalized intersections. Zhu. [4] took harbor bus stops as the research object and adopted MATLAB source language programming and simulation method to analyze the influence of setting conditions of stops and bus proportion factors on vehicle traffic at intersections. He et al. [5] analyzed the bus stop process, selected bus stop in a straight line section for traffic investigation, and used VISSIM simulation software to verify and analyze the rationality of bus stop setting.
Meanwhile, traffic operation is a dynamic process, and VISSIM can effectively reflect this process [6]. Therefore, VISSIM simulation software is widely used in the analysis of intersection capacity. Pan et al.[7-10] used VISSIM simulation software to analyze traffic efficiency at signalized intersections and put forward an optimal design scheme.

To sum up, this paper takes bus stations at adjacent signal intersections as the research object and uses VISSIM simulation software to obtain the best position of stations at adjacent intersections with different flows, so as to improve the capacity of signal intersections. Taking Xuzhou mining university station as an example, the validity of the recommended location is verified by comparing the recommended location with the existing one.

2. Impact of delays on bus stops adjacent to signalized intersections

2.1. The evaluation index

There are many evaluation indexes for signalized intersections, most of which take delay, average queue times, vehicle travel time and parking times as evaluation indexes. In this paper, the delay is selected as an evaluation index.

The parameter and variables are listed as follows: \(d\): average signal delay per vehicle in each lanes; \(d_1\): uniform delay; \(d_2\): random additional delay; \(C\): period length; \(\lambda\): green letter ratio; \(x\): saturation; \(CPA\): lane capacity; \(T\): duration, equal to 0.25h; \(e\): correction coefficient of single intersection signal control type, timing signal \(e = 0.5\).

The delay at signalized intersections reflects the loss of vehicle travel time and the obstruction of vehicles at signalized intersections. The calculation formula is as follows:

\[
d = d_1 + d_2
\]

\[
d_1 = 0.5C \frac{(1 - \lambda)^2}{1 - \min(1, x)\lambda}
\]

\[
d_2 = 900T \left[ (x - 1) + \sqrt{(x - 1)^2 + \frac{8ex}{CPA*T}} \right]
\]

Equation (1) calculates the average delay time for each lane; Equation (2) calculates the uniform delay; Equation (3) calculates the stochastic additional delay time.

2.2. Impact of delay on the bus stop adjacent to the intersection

Due to the different influence mechanism of bus stations on signalized intersections, the generation of delay is different. For the bus station upstream of the adjacent intersection, the delay is reflected in the delay caused by the vehicles in the outermost lane when the bus stops occupying the station, and the extra time caused by the traffic flow caused by the management and control of signal lights. When the bus stop is located at the downstream of the adjacent intersection, it is mainly manifested as the impact of the bus stop on the social vehicles entering the exit road.

2.3. Simulation results of two-way six - lane bus station

In this paper, the stations are divided into upstream and downstream stations according to the straight-line station and the bay station, and the simulation is carried out with the stations of these four different forms. The simulation time is 4000s, and the average of the vehicle delays obtained from 5 different seeds is taken as the simulation result to explore the relationship between the location of the bus station, the traffic volume and the delay of the vehicle.

In this paper, the simulation results of two-way six-lane upstream straight-line platform are analyzed as an example, as shown in Figure 1.
When the location of the bus station is fixed, the average delay increases with the increase of traffic volume. When the traffic volume is constant, the average delay decreases with the increasing distance between the platform and the entrance approach stop line, and the speed of delay decreases with the different traffic volume (saturation). The results were similar for the other three types of platforms.

By sorting out the simulation results, the distance corresponding to the inflection point of the average delay curve is selected as the recommended position of bus stop at the intersection of six lanes adjacent to the signalized intersection in both directions, and the results are shown in Table 1.

Table 1. Recommend location of two-way six-line signalized intersection at the bus station

| Station form | Traffic volume (pcu/h) | Inlet saturation | Distance between station and parking line (m) |
|--------------|------------------------|------------------|---------------------------------------------|
| Upstream     |                        |                  |                                             |
| linear       | 1500                   | 0.637            | 110                                         |
|              | 1400                   | 0.594            | 110                                         |
|              | 1300                   | 0.522            | 110                                         |
|              | 1200                   | 0.510            | 90                                          |
|              | 1500                   | 0.637            | 110                                         |
| Upstream     |                        |                  |                                             |
| harbor       | 1400                   | 0.594            | 100                                         |
|              | 1300                   | 0.522            | 90                                          |
|              | 1200                   | 0.510            | 80                                          |
| Downstream   |                        |                  |                                             |
| linear       | 1400                   | —                | 60                                          |
|              | 1300                   | —                | 50                                          |
|              | 1200                   | —                | 40                                          |
| Downstream   |                        |                  |                                             |
| harbor       | 1400                   | —                | 60                                          |
|              | 1300                   | —                | 50                                          |
|              | 1200                   | —                | 40                                          |

3. Case Study

3.1. Analysis of the situation
Take Xuzhou mining university station, which is located at the southern entrance of the CP lotus intersection. The intersection is a typical intersection, Jinshan East road is the east-west direction of the main road, Jiefang South road is through the north-south direction of Xuzhou city main road. According to the geometric line of the intersection, the plan of the intersection is drawn, as shown in Figure 2.

![Figure 2. Plane map of the lotus flower intersection](image)

In this paper, we select 1h during peak hours to investigate each import by vehicle type, and get the traffic flow and flow direction of each import in peak hours after conversion, as shown in Table 2.

| Import road | Exit road | Traffic volume (pcu/h) | Proportion |
|-------------|-----------|------------------------|------------|
| East import | West exit | 873                    | 0.69       |
|             | South exit| 1264                   | 0.24       |
|             | North exit| 308                    | 0.07       |
|             | East exit | 83                     | 0.47       |
| West import | South exit| 1173                   | 0.24       |
|             | North exit| 278                    | 0.29       |
|             | East exit | 340                    | 0.20       |
| South import| West exit | 1612                   | 0.30       |
|             | North exit| 813                    | 0.50       |
|             | East exit | 150                    | 0.11       |
| North import| West exit | 1389                   | 0.28       |
|             | South exit| 850                    | 0.61       |

This intersection is a typical four-phase control, the signal period is 134s, and there is 3s yellow time between each phase. Signal timing scheme is shown in Figure 3.

![Figure 3. Signal timing diagram](image)
The capacity saturation at the south entrance of the intersection is calculated according to the survey data, as shown in table 3.

Table 3. Intersection capacity and saturation

| Traffic volume (pcu/h) | Saturation rate (pcu/h) | Saturation | Traffic capacity (pcu/h) |
|-----------------------|-------------------------|------------|-------------------------|
| 1590                  | 2627                    | 0.622      | 2133                    |

3.2. Simulation results and optimization

The mining university station is located at the south entrance of CP Lotus intersection. The distance between the station and the stop line is 90m. According to the simulation of the existing position shown in Figure 3, the delay time of all trains is 89.57s.

The saturation of southern entrance is 0.622. According to the data in Table 1, the recommended position of bus stop upstream at the adjacent intersection is 106m by interpolation method. In VISSIM simulation software, only the distance between station position and stop line is adjusted to 106m, and other basic parameters are kept unchanged for simulation, as shown in Figure 4.

![Figure 4. Simulation of optimization location](image)

Table 4. Comparison of results before and after optimization

| Traffic volume before and after optimization | Traffic capacity before and after optimization | Saturation | Average vehicle delay before and after optimization | Distance between station and parking line |
|---------------------------------------------|-----------------------------------------------|------------|---------------------------------------------------|------------------------------------------|
| Before 1634                                 | 2133                                          | 0.622      | 89.57                                             | 90                                       |
| After 1634                                  | 2133                                          | 0.622      | 82.96                                             | 106                                      |

After 10 times of simulation, it is found that the average delay of buses after station location optimization is 82.96s, which is 7.38% lower than the average delay of buses at the existing bus station. That is to say, taking the average delay of buses as an index, the average delay of cars can be effectively reduced by reasonably moving station location, and the effectiveness of the recommended position of bus station is also verified.

4. Conclusion

This paper discusses the influence of bus station on vehicle delay at adjacent intersections. Taking the average vehicle delay as the index, this paper analyzes the influence mechanism of the setting of different types of bus stations in six lanes in two directions on the vehicle delay, and obtains the recommended positions of different types of bus stations under different lines and flows. The effectiveness of the recommended location is verified by taking Xuzhou mining university station as an example.

Acknowledgments

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