Research on Traffic Optimization of Urban Four-Phase Intersections Based on VISSIM

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Abstract: In order to effectively solve the congestion problem of mixed intersections, improve traffic efficiency, and improve the current congestion situation of urban road network, this paper takes the mixed traffic flow intersection of Shanghai Road and Guyan Street in Yuanzhou District of Guyuan City as an example to carry out optimization research, collect traffic flow and signal timing data during peak hours through field investigation, and establish a microscopic road model by using VISSIM software. Through simulation, the indexes such as vehicle delay and queue length are obtained. Then the lane function of the model is divided, the signal timing is optimized by Webster algorithm and Fuzzy algorithm, and the comparison analysis is carried out. The simulation results show that the vehicle delay and queue length after Fuzzy optimization are greatly reduced, and the traffic running condition is significantly improved, thus verifying the scientificity and rationality of the optimization scheme.

Keywords: Intersection; Vehicle Delay; Queue Length; Webster Algorithm; Fuzzy Algorithm; VISSIM

1. The intersection status quo

1.1 Distribution of plane intersections

Guyuan City Yuanzhou District Shanghai Road is an urban main road, the direction is east-west. It forms an intersection with Guyan Street, with the east entrance of Shanghai Road, Shanghai Road west road entrance and the south entrance of Guyan Street are four lanes, with left turn, straight turn, straight turn and right turn lanes. The north entrance of Guyi Street is three lanes, with left turn, turn left and turn right turn. The east exit and west exit of Shanghai Road and the south exit of Guyi Street are four lanes, while the north exit of Guyi Street is one lane. The traffic flow of the two roads is relatively large during the daily peak period, and the vehicle congestion is more serious. The specific condition of the intersection is shown in Figure 1.

Figure 1: Current Situation of Shanghai Road - Guyan Street Intersection

2. Status signal timing

The intersection of Shanghai Road-Guyi Street is a four-phase signal timing scheme with a period of 120s, and the yellow light and the waiting time between the phases are 4s. The current phase timing is shown in Figure 2.

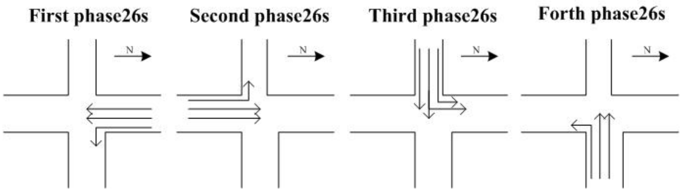

Figure 2: Current Phase Timing of Intersection

1.2 Intersection traffic flow data

The traffic flow data at the intersection is completed by 4 people in 10 days. This survey mainly takes three peak sections of 300m roads at the intersection 7:30-9:00,11:00-12:30 and 18:001-19:30. According to statistics, it is found that the vehicle composition of the intersection is 95% by cars and buses account for 5%. The specific traffic flow of Shanghai Road-Guyi Street intersection is shown in Table 1.

Table 1: Current Traffic Flow

No.	lane	flow（pcu/h）	traffic capacit（pcu/h）	flow ratio
1	East-straight	1020	1532	67%
2	East-left	576	756	76%
3	East-right	230	761	30%
4	West-straight	1492	1532	97%
5	West-left	680	756	90%
6	West-right	465	761	61%
7	North-straight&right	580	756	77%
8	North-straight&left	650	756	86%
9	North-left	680	756	89%
10	South-straight	650	1512	43%
11	South-left	320	756	42%
12	South-right	350	761	46%

According to the data in Table 1, it can be concluded that the southbound section of Shanghai Road-Guyan Street intersection has sufficient capacity and great redundancy of [1] on the premise of meeting the requirements of existing vehicles. However, the east-west and north sections are lack of capacity, which needs to be further optimized VISSIM.

2. Made by VISSIM

The traffic situation of the intersection of Shanghai Road-Guyan Street was analyzed by VISSIM simulation software. First, the data of traffic flow and signal timing are input into the software, and then the traffic control module and traffic flow module [1] are set. The simulation time is set to 600s, and the results are output once every 300s. The method of node detection is adopted to obtain the vehicle delay and queue length of each inlet road of the intersection. The simulation model is shown in Figure 3, and the simulation data are shown in Table 2.

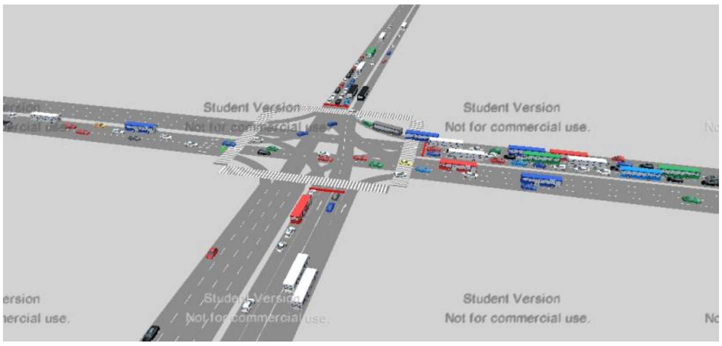

Figure 3: Current VISSIM Simulation Status

Table 2 VISSIM Simulation Status Data

phase	lane	Maximum queue length	Vehicles No.	Vehicle delay time	Stops No.	Emissions CO	Emissions Nox	Emissions VOC
I	West-straight	52.9	48.0	45.7	0.8	61.8	12.0	14.3
	West-left	69.5	22.0	55.0	1.0	33.2	6.5	7.7
	West-right	0.0	82.0	0.4	0.0	22.1	4.3	5.1
II	East-left	84.9	35.0	53.2	0.9	51.1	10.0	11.9
	East-straight	121.9	91.0	48.0	0.9	124.2	24.2	28.8
	East-right	106.6	82.0	11.8	0.7	60.6	11.8	14.0
III	South-left	78.6	47.0	41.8	0.8	59.5	11.6	13.8
	South-straight	94.3	61.0	49.1	0.9	85.9	16.7	19.9
	South-right	0.0	50.0	0.2	0.0	12.5	2.4	2.9
IV	North-left	277.5	30.0	54.8	0.9	43.6	8.5	10.1
	North-straight&left	277.6	32.0	70.9	1.0	55.1	10.8	12.8
	North-straight&right	277.5	21.0	54.1	0.8	32.3	6.4	7.5

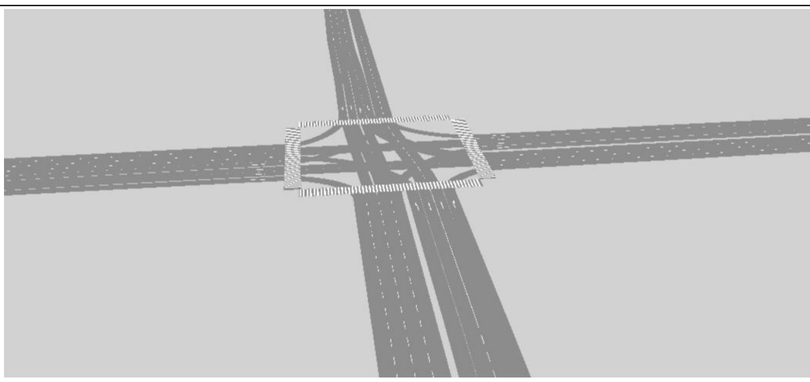

Figure 4 Optimization of Shanghai Road Guyan Street Intersection

3.2 Signal timing optimization

The signal timing is optimized by two methods, Webster method and fuzzy method. The optimal timing scheme is selected by VISSIM simulation.

3.2.1 Webster Method and timing optimization

Phase I of Shanghai Road-Guyi Street intersection is straight line and left turn at the west entrance, phase II is straight line and left turn at the east entrance, phase III is straight line and left turn at the south entrance, and phase IV is straight line and left turn at the north entrance. The flow of phase I and II at the intersection is 1500 vehicles / hour, the flow of phase III and IV is 800 vehicles / hour, the east-west saturated traffic volume is 1532 vehicles / hour, the north-south saturated traffic volume is 1512 vehicles / hour, the loss time per phase is 2s, and the yellow light time is 3s. The full red time of the signal light is 0s.

（1）The optimal cycle length was calculated C_0

from $q_i = \frac{y_i}{n}$ get：$q_1 = q_2 = 375$ Vehicle / h，$q_3 = q_4 = 250$ Vehicle / h

Total loss time $L = nl + AR = 8$s.

from $Y_i = \frac{q_i}{S_i}$ the traffic flow ratio of each critical lane：

$$Y_1 = Y_2 = 0.245, Y_3 = Y_4 = 0.165$$

$$Y = Y_1 + Y_2 + Y_3 + Y_4 = 0.82，C_0 = (1.5L + 5)/(1 - Y) = 94.4s$$

round number $C_0 = 94s$。

（2）Calculate the efficient green light time：

$$G_e = C_0 - L = 86s$$

$$g_{e1} = g_{e2} = G_e \times \frac{Y_1}{Y} = 25.7s$$

$$g_{e3} = g_{e4} = G_e \times \frac{Y_3}{Y} = 17.3s$$

（3）Calculate the actual green light time

from $G_i = g_{ei} - y_i + l_i$ get $G_1 = G_2 = 24.7s$ $G_3 = G_4 = 16.3s$。

（4）When determining each phase lamp：

Each phase yellow lamp is taken for 3s, so each phase lamp is as shown in Table 3.

Table 3 Time Distribution Table for Each Phase of Lamp

phase	I	II	III	IV
Green light length（s）	25	25	16	16
Yellow light length（s）	3	3	3	3

Cycle $C = 94$s。

3.2.2 Fuzzy algorithm（Fuzzy way）Time allocation optimization

3.2.2.1 Obfuscation

The design uses a fuzzy controller with two input and one output signal. The input variable is the maximum vehicle queue length (L) of the current phase and the vehicle delay (D) of the next passage phase, and the output variable is the green light delay (T).

L、D、T and fuzzy subsets are shown in Table 4.

Table 4 Controller Signal Fuzzification Parameters Table

name	Basic Domain	Fuzzy subset	Fuzzy domain	Quantizer
L	[0,300]	{VS,S,M,L,VL}	[0,10]	1/30
D	[0,100]	{VS,S,M,B,VB}	[0,10]	1/10
T	[-15,15]	{VS,S,M,L,VL}	[-5,5]	1/3

3.2.2.2 Fuzzy inference

In this paper, we use the form of "IF A and B THEN C" to set the fuzzy rules and use the Mamdanani method for the fuzzy inference [2]. The complete fuzzy inference rules are shown in Table 5.

Table 5 Fuzzy Reasoning Rules of the Controller

L	D				
	VS	S	M	B	VB
VS	M	S	L	VL	VL
S	L	M	L	VL	VL
M	L	S	L	VL	VL
L	VL	S	S	L	L
VL	VL	VS	S	S	L

3.2.2.3 Solution fuzzy

In this paper, the input and output surface of the fuzzy controller and the precise output variable [2-3] of the corresponding output variable green delay (T). The Rule viewer and surf viewer views are shown in Figure 5.

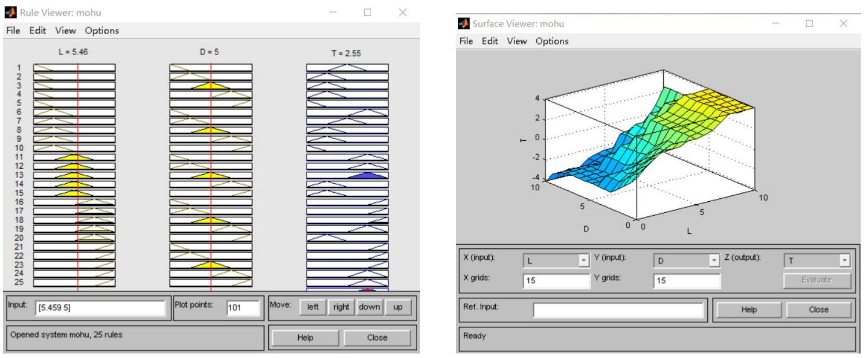

Figure 5 Rule viewer view and surface viewer view

3.2.2.4 When determining the optimization lamp

In this paper, we take the intersection of Shanghai Road-Guyan Street in Yuanzhou District of Guyuan City as the research object, obtain the node data of the intersection, and optimize the signal light timing according to the fuszy fuzzy controller to get the green light extension time corresponding to the four phases, and thus calculate the green light time of each phase. Each phase lamp is as shown in the table.

Table 6 Fuzzy Method Timing Table

phase	Maximum queue length	Vehicle delay time	Green light delay(T)	green time(s)
I	61.64	44.74	-7.5	17
II	88.45	41.57	-3.66	21
III	92.8	38	-2.2	23
IV	274	42.88	7.59	32

3.3 Comparison of the results of each optimized timing method

During the peak traffic state of Shanghai Road and Guyan Street intersection, the Webster method and fuzzy method were optimized respectively, and the VISSIM software was used to replan the intersection road and vehicle path, readjust the traffic signal control strategy, and continue to use the node simulation data [4-6]. The simulation data obtained by Webster method and fuzzy method before and after road planning at Shanghai Road-Guyan Street intersection are shown in Table 7. The comparative data map before and after the intersection optimization is shown in Figure 6 and Figure 7.

Table 7 Statistical Table of Simulation Data for Each Timing Method

Timing method	Queue length (maximum)	Number of vehicles	Average Vehicle Delay	Emissions Nox	Emissions VOC	Stops No.
original	277.6	653	37.1	141.7	168.7	0.68
After road planning	277.4	639	28.4	118.5	141.1	0.60
Webster	260.3	671	34.2	134.4	160.1	0.58
fuzzy	230.1	710	32.1	141.9	169.0	0.65

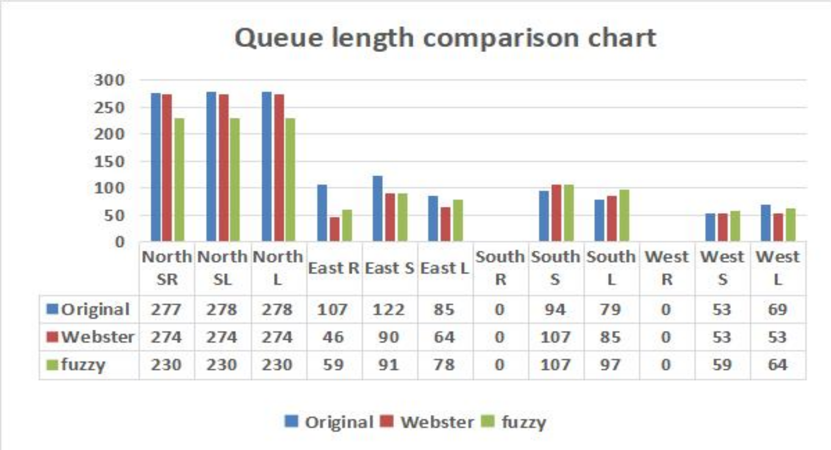

Figure 6 Comparison of queue length before and after optimization

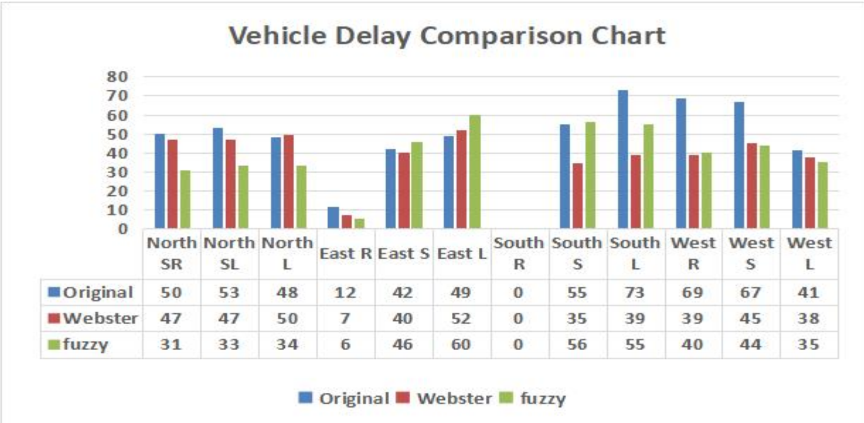

Figure 7 Comparison of Vehicle Delay Time before and after Optimization

By comparing the data before and after road optimization at the intersection of Shanghai Road-Guyan Street, it can be seen that although the vehicle queuing length is unchanged after the road planning, the vehicle delay time is reduced by 23%, and the emission Nox and VOC are reduced by 20% and 16% respectively, indicating that the road planning is effective. The continued Webster method and fuzzy method shortened the vehicle queue length by 6% and 17% respectively, and reduced the vehicle delay time by 8% and 13% respectively.

For specific roads, the queuing length of vehicles and the most effective, and each lane at the north import was reduced from 277m to 230m, improving by 17%. The straight line at the east entrance is 122m to 91m, an improvement of 25%, and the left turn at the east entrance is reduced from 85m to 78m, an improvement of 8%. The delay time of vehicles in the straight right, straight left and left lanes at the north entrance was reduced by 30%, 37% and 29% respectively, while the delay time of straight and left vehicles in the west entrance decreased by 34% and 15% respectively, effectively improving the congestion problem in the north entrance and east-west directions during peak periods. At the same time, the delay time of vehicles imported from the east and the south has increased, but the overall traffic conditions in these lanes are good, so the impact is small. Overall, the optimized road conditions have been significantly improved.

3. Conclusion

This study focuses on the traffic optimization problem at urban four-phase intersections based on VISSIM simulation software. Through the simulation experiment, the traffic problems of the intersection are analyzed, and then the intersection lane is replanned, and the signal timing of Webster method and fuzzy method is optimized. The main data before and after the optimization are compared and analyzed. The results show that the signal timing scheme of the intersection is optimal. The traffic flow efficiency and flow processing capacity can be significantly improved by rationally adjusting the signal control parameters. This study has certain guiding significance for urban traffic planning and traffic management, and can provide theoretical and methodological support to achieve a more efficient, safe and environmentally friendly transportation system [7].

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