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Traffic Impact Analysis of Urban Intersections with Comprehensive Waiting Area on Urban Intersection Based on PARAMICS

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Abstract

To improve the traffic operation and take advantage of the space resource, left-turn vehicles waiting area and straight vehicles waiting area are adopted separately at intersection at home and abroad, but there is not much research for using left-turn and straight waiting area together at the same intersection. Research using simulation software PARAMICS combining with programming API to simulate a specific comprehensive waiting area in Guangzhou city under nine different traffic volumes for three conditions: following control strategy, underutilizing control strategy and without control strategy. By evaluating the following four indexes: link delay, queue length, link average speed and passing vehicles, the simulation results indicate that the improving effect of following control strategy is superior to the underutilizing control strategy. Implementing comprehensive waiting area and in conjunction with the following control strategy can improve traffic operation when traffic volume is larger than the surveyed situation volume while the improvement is more effectively when traffic volume continues to increase. Setting comprehensive waiting area cannot improve intersection traffic operation but will worsen the traffic operation when traffic volume is less than the surveyed situation volume.

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Keywords: comprehensive waiting area; PARAMICS simulation; API plugin; following control strategy; underutilizing control strategy; without control strategy

1 INTRODUCTION

The acceleration of the process of urbanization, modernization and motorization results in the large burden of Chinese urban transport. For large and medium-sized cities, road construction has basically been saturated. Road construction is not a good way to improve traffic operation and should optimize traffic management and traffic organization. Implementing some special form of transportation organization can play a more significant role in raising the intersection level of service for some high-saturation intersections.

Left-turn vehicles waiting area and straight vehicles waiting area are usually adopted at intersection at home and abroad, these two forms of organizations are based on the idea of space for time.

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A traffic organization named shared-parking area method and signal phase sequence were proposed (Yuan, et al., 2008). The research on phase sequence can be used for reference for comprehensive waiting area.

Speed limit program under the highway accident conditions was compared and evaluated, combined with PARAMICS microscopic simulation (Zheng, et al., 2004); API function was applied to program plug-in to simulate ITS control and guidance strategies (Zhuang, et al., 2005). Using PARAMICS simulation platform for quantitative simulation and programming API plug-in to realize the control strategy can be learned in this paper.

Research on left-turn waiting area and straight waiting area was conducted respectively, and did not focus on comprehensive usage for left-turn waiting area and straight waiting area (Li, et al., 2011; Ji, et al., 2006; Wang, 2009).

This paper applies PARAMICS to simulate the traffic operation in the comprehensive waiting area adopted by a certain entrance at a crossing intersection and take a traffic impact analysis for the comprehensive waiting area.

2 TRAFFIC IMPACT ANALYSIS OF COMPREHENSIVE WAITING AREA BASED ON PARAMICS MICROSCOPIC SIMULATION

2.1 Introduction to Comprehensive Waiting Area

Comprehensive waiting area has been used in practice in Shanghai and Guangzhou. Drivers do not quite understand the intersection control strategy because comprehensive waiting area is a new intersection control strategy. This paper takes the comprehensive waiting area, located at between the Shangdu Road and Bingjiang Road crossing intersection and the T-intersection, as an example to introduce comprehensive waiting area. Comprehensive waiting area has two stop lines, the first stop line locates at the front of the comprehensive waiting area and the second stop line locates at the end of the comprehensive waiting area such as figure 1 shows. The comprehensive waiting area needs to set a two-phase signal control at T-intersection. The first phase is left-turn and U-turn phase, and the second phase is straight and right-turn phase.

The study will conduct simulation under three conditions, namely following control strategy (abbreviated as FCS), underutilizing control strategy (abbreviated as UCS) and without control strategy (abbreviated as WCS).

The FCS situation means when the signal is in the first phase, left-turn vehicles can drive into the comprehensive waiting area occupying three entrances and U-turn vehicles can turn around while straight vehicles and right-turn vehicles stop at the first stop line shown as the state 1 of figure 1, and when the signal is in the second phase, straight vehicles and right-turn vehicles can drive into the comprehensive waiting area occupying three entrances while left-turn vehicles and U-turn vehicles stop at the first stop line shown as the state 2 of figure 2. T-intersection signal control has all-red time and all vehicles should stop at the first stop line shown as the state 3 of figure 3.

The UCS situation means left-turn vehicles just occupy the inside lane of the comprehensive waiting area under state 1 and straight vehicles just occupy the lateral two lanes under state 2. State 3 is the same as FCS. Since now drivers do not understand the correct comprehensive waiting area control strategy, the UCS situation is the current situation of the surveyed comprehensive waiting area.

The WCS situation means there is no comprehensive waiting area and T-intersection has not signal control.

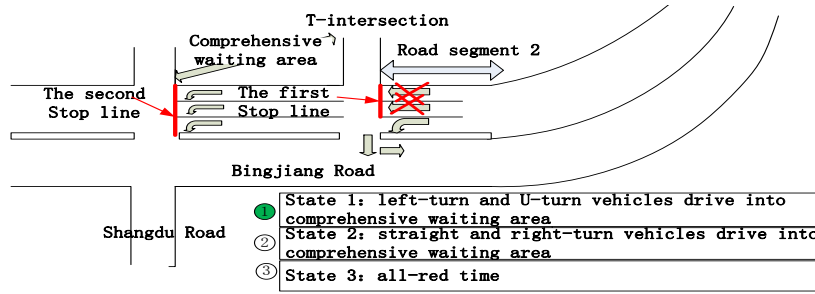


Figure 1. Vehicle driving schematic diagram under state 1 in comprehensive waiting area

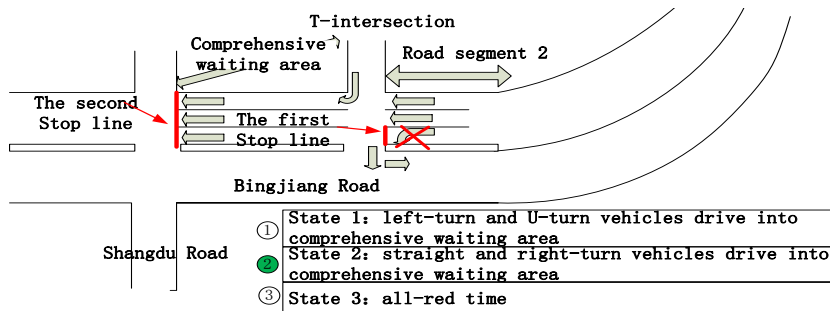


Figure 2. Vehicle driving schematic diagram under state 2 in comprehensive waiting area

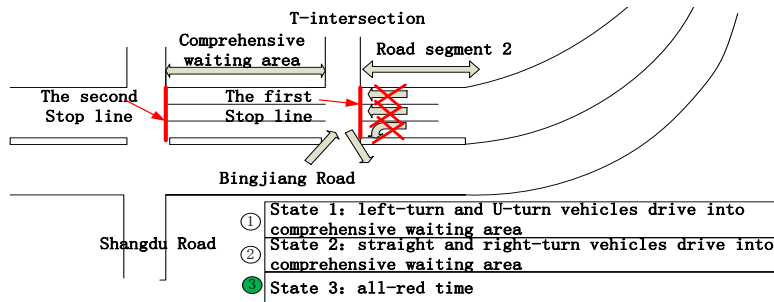


Figure3. Vehicle driving schematic diagram under state 3 in comprehensive waiting area

2.2 PARAMICS Introduction

PARAMICS mainly consists of six main tool modules: Modeller, Processor, Analyser, Programmer, Estimator, Monitor(Quadstone Limited,2003). PARAMICS consists of four kinds of functions: QPO, QPX, QPG and QPS. QPO let the user replace algorithms / routines in the core PARAMICS network with their own code; QPX let the user add new code to the PARAMICS simulation; QPG let the user query the value and state of objects in the PARAMICS model and QPS let the user set values, states and action for objects in the PARAMICS model.

Call the above four API functions through C language to program a plug-in and load it into PARAMICS network in order to achieve the control strategy(Zhuang, et al., 2005).

2.3 PARAMICS Traffic Impact Analysis Process

Traffic impact analysis (referred to as TIA) plays an active role to ease urban traffic contradictions (Wang, et al., 2009). Intelligent Transportation Systems (ITS) traffic impact analysis is one of the key technologies in ITS research and application, and is also an important part of the TIA. ITS aims at the existing road traffic systems to control and regulate the traffic flow, not simply rely on the infrastructure to improve the traffic situation (Zheng, et al., 2004). PARAMICS realizes the real control strategy in virtual network through the API function and conducts the analysis and evaluation of the output. This study will conduct simulation under FCS, UCS and WCS. Each strategy selects nine different traffic volumes, and a PARAMICS simulation procedure is shown in Figure 4.

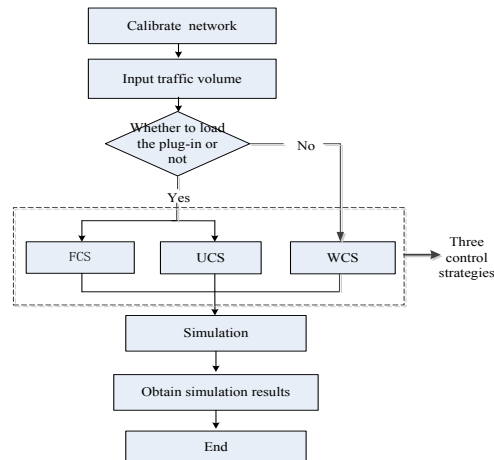


Figure 4. A PARAMICS simulation process

2.3.1 Data Preparing

(1) Road network data

Building road network model needs actual road conditions as a basis including road geometry of intersection, numbers of entrances, traffic marking and so on.

(2) Traffic flow data

Use video to shoot the crossing intersection and T-intersection, and collect vehicle statistics according to driving direction, lane and vehicle type, and transform mixed traffic volume into standard traffic volume.

(3) Signal phase

Signal phase data contain signal cycle, phase number, phase sequence, red time, green time, amber time and phase difference.

(4) Vehicle speed

The spot speed survey is conducted at the evening peak period 17:00-19:00 and the survey method is manual survey.

2.3.3 OD Setting

This study only focuses on comprehensive waiting area located at the east entrance of Shangdu Road and Bingjiang Road crossing intersection, so only requires to set specific OD in order to meet the east entrance traffic operation, and does not need the OD estimation tool in PARAMICS to estimate the whole network OD matrix.

2.3.4 Parameter Calibration

This study takes traffic volume and spot speed as the calibration parameter. Input the actual surveyed traffic volume and spot speed into PARAMICS and make a comparison with the simulation value. The network is available if deviation is within the acceptable range, and if deviation is without the acceptable range, the headway, vehicle reaction time and desired speed require to be calibrated to meet the network accuracy requirements.

2.3.5 Plug-in Programming

A specific plug-in needs to be programmed and loaded to the network in order to realize the comprehensive waiting area signal control strategy. Plug-in algorithm flowchart is shown as figure 5.

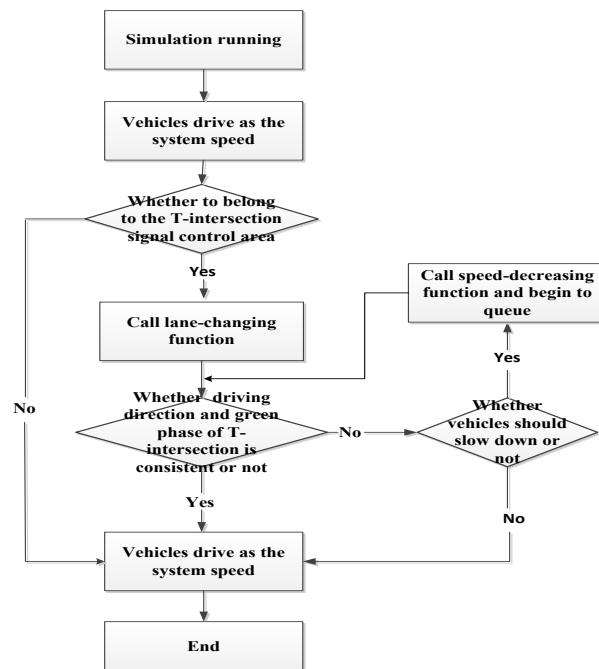


Figure 5. Plug-in algorithm flowchart

2.3.6 Simulation Experiment

In this paper, simulation will be conducted under FCS, UCS and WCS. Input nine different traffic volumes with five simulation seeds respectively under three kinds of control strategies. The nine traffic volumes are 0.6Q, 0.7Q, 0.8Q, 0.9Q, Q, 1.1Q, 1.2Q, 1.3Q and 1.4Q. Q stands for the actual surveyed traffic volume.

Since the crossing intersection delay may be passed on to the T-intersection, the comprehensive waiting area and a certain distance before T-intersection are combined together to form a system. The paper studies the system traffic operation influenced by the comprehensive waiting area under three control strategies. The system consists

of 92-meter comprehensive waiting area and 200-meter road segment 2 (shown as figure 1). The analysis of the four indexes under three control strategies aims at the system.

These four indexes are link delay, queue length, link average speed and passing vehicles. The link delay is the sum of the comprehensive waiting area delay and road segment 2 delay; the queue length is the sum of the comprehensive waiting area queue length and segment 2 queue length; the link average speed is the average of the comprehensive waiting area and road segment 2 vehicle speed, and the passing vehicles is the passing vehicles of T-intersection.

3 CASE STUDY

3.1 Intersection Current Situation

(1) Road geometry characteristics

After surveying, the current situation and PARAMICIS simulation road network is shown as figure 6 and figure 7.

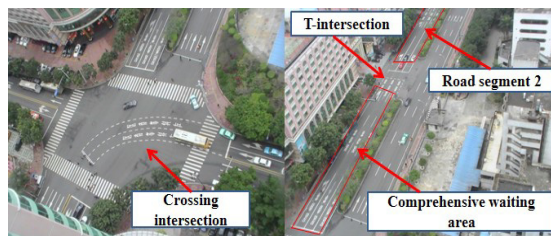


Figure 6. Current situation of intersection and T-intersection

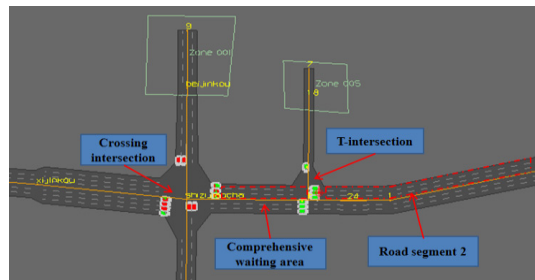


Figure 7. PARAMICIS road network

(2) Traffic volume

The current situation standard traffic volume is shown as table 1.

Table 1. Current Standard Traffic Volume in Crossing Intersection and T-intersection

Straight (unit:pcu/h)	Left (unit:pcu/h)	U-turn in T- intersection (unit:pcu/h)	Right-turn in crossing intersection (unit:pcu/h)	Right-turn in T-intersection (unit:pcu/h)
1461	139	90	46	16

(3)Signal phase

The signal control of the crossing intersection and T-intersection is a signal linkage control with 180s signal cycle and 27s phase difference. The crossing intersection has six phases shown as Figure 8 and the T-intersection has 2 phases shown as Figure 9.

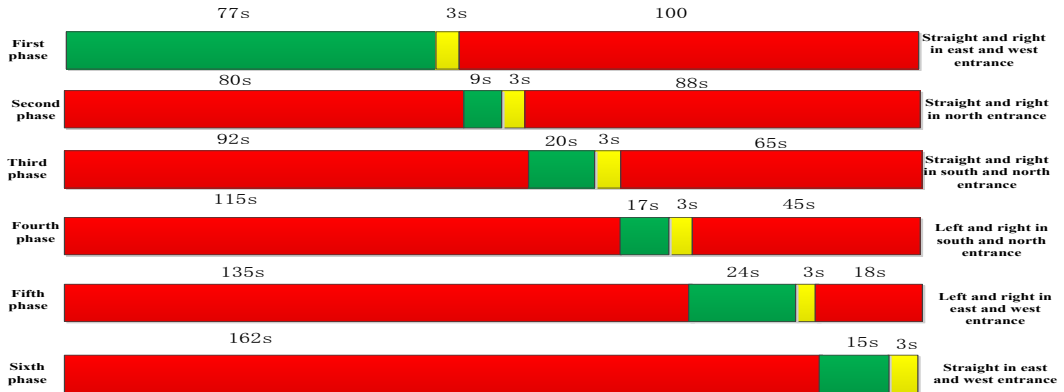


Figure 8. Signal Phase of Crossing Intersection



Figure 9. Signal Phase of T-intersection

(4) Vehicle speed

In this study, the surveyed spot vehicle speed is 20.843km/h and applied to input the PARAMICS as the simulation speed.

3.2 Parameters Calibrating

Input the actual surveyed traffic volume 1752pcu/h and spot vehicle speed 20.843km/h into PARAMICS to simulate ,and the simulation spot vehicle speed and traffic volume is 1717pcu/h and 20.485km/h respectively. Obviously, there is a small deviation which can be ignored and the PARAMICS road network can be used to do simulation experiments.

3.3 Traffic Simulation

According to section 2.3.6 simulation method, the four evaluation indexes are obtained shown as table 2.

Table 2. Four evaluation indexes value of different control strategies under 9 traffic volumes

Index	Strategy	Traffic volume				
		0.6Q	0.7Q	0.8Q	0.9Q	Q
Link delay (s)	UCS	36.9	40.2	40.2	46.2	52.2
	FCS	31.4	33.1	33.7	35.8	39.5
	WCS	28.1	30.5	34.1	37.6	51.8

Queue length (veh)	UCS	17	18	18	22	25
	FCS	16	15	17	19	22
	WCS	9	11	15	17	21
Passing vehicles (pcu/h)	UCS	990	1180	1180	1508	1679
	FCS	990	1180	1318	1517	1681
	WCS	1009	1188	1351	1529	1695
	Inputting value	1057	1233	1409	1585	1761
Link average speed (km/h)	UCS	21.7	20.5	19.4	17.7	16.0
	FCS	23.3	22.4	21.9	20.7	19.3
	WCS	28.8	26.7	24.6	22.9	19.3

Continue the Table2

Index	Strategy	Traffic volume				
		Q	1.1Q	1.2Q	1.3Q	1.4Q
Delay (s)	UCS	52.2	91.9	112.3	119.3	118.8
	FCS	39.5	40.1	79.4	76.4	82.9
	WCS	51.8	84.9	129.6	143.4	149.3
Queue length (veh)	UCS	25	33	36	37	37
	FCS	22	23	28	25	33
	WCS	21	29	39	41	42
Passing vehicles (pcu/h)	UCS	1679	1804	1826	1817	1839
	FCS	1681	1843	1880	1919	2257
	WCS	1695	1830	1896	1916	1936
	Inputting value	1761	1937	2113	2289	2465
Link average speed (km/h)	UCS	16.0	11.3	10.0	9.5	9.6
	FCS	19.3	18.9	15.2	14.9	13.9
	WCS	19.3	13.5	8.8	7.9	7.2

Note: Q=1761pcu/h(the traffic volume in current traffic situation)

3.4 The Analysis of Simulation Result

After simulating, the outputs are analyzed shown as figure 10,figure 11,figure 12 and figure 13.

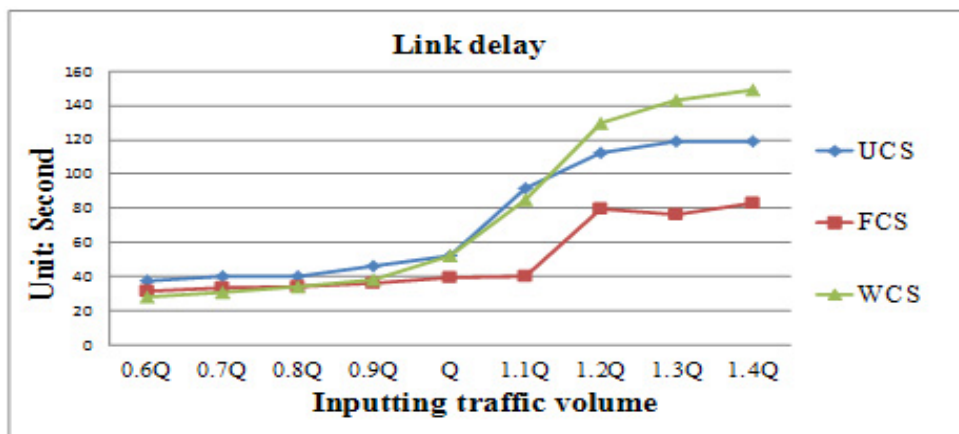


Figure 10. Link delay comparison under different traffic volumes

From figure 10, when the inputting traffic volume is less than Q, the link delay under the FCS and WCS is basically the same and the link delay under UCS is a little higher than the other two strategies. When the inputting volume is Q, the FCS is superior to the WCS and UCS by decreasing delay 5s. When the volume continues to increase, the improvement of FCS becomes more obvious, and the UCS is superior to the WCS until the volume is larger than 1.3Q.

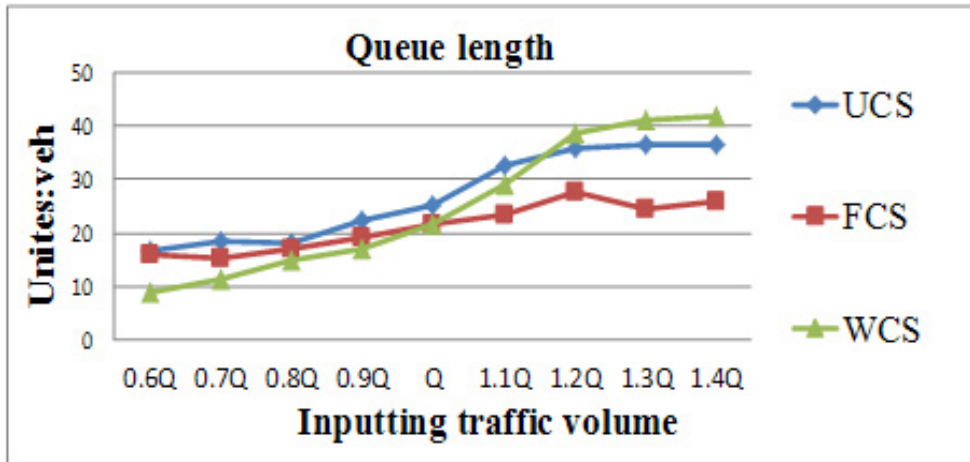


Figure 11. Queue length comparison under different traffic volumes

From figure 11, when the inputting traffic volume is less than Q, the queue length under WCS is shorter than the queue length under the other two strategies. When the inputting volume is Q, the queue length under FCS and WCS is shorter than the queue length under UCS by about 5 vehicles. When the volume continues to increase, the queue length decreases obviously under FCS, and the UCS is superior to the WCS until the volume is larger than 1.15Q.

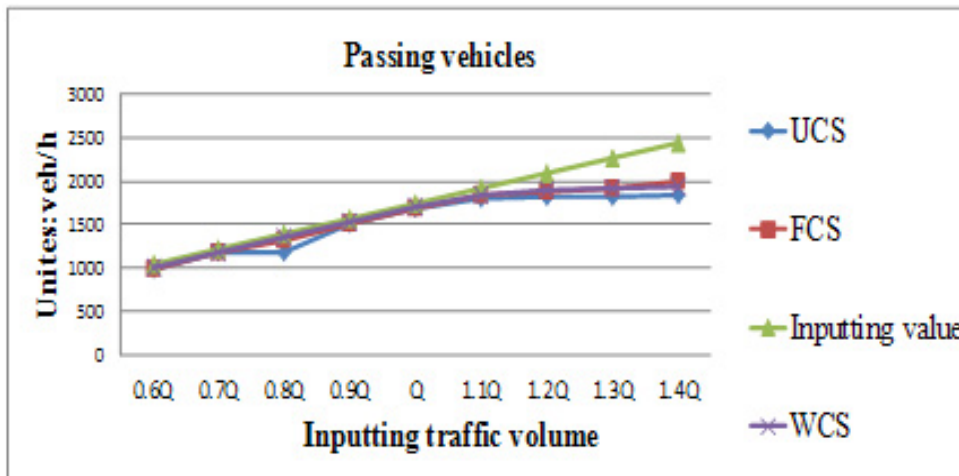


Figure 12. Passing vehicles comparison under different traffic volumes

From figure 12, When the inputting traffic volume is in $0.6Q$ - $1.1Q$, the passing vehicles under the three control strategies are basically the same, and when the inputting volume is larger than $1.1Q$, the three control strategies all cannot improve the passing vehicles.

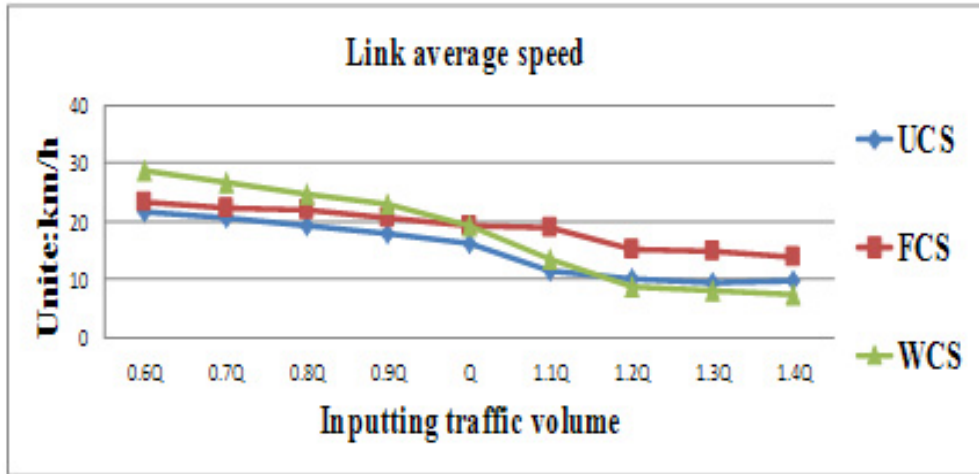


Figure 13. Link average speed under different traffic volumes

From the figure 13, when the inputting traffic volume is in $0.6Q$ - $1.0Q$, the link average speed under WCS is higher than the other two strategies. When the inputting volume is Q , the link average speed under FCS and WCS is basically the same and a little higher than the vehicle speed under the UCS by increasing 3km/h . When the inputting volume is larger than Q , the improvement of FCS is more obvious, and the UCS is superior to the WCS until the volume is larger than $1.15Q$.

4 CONCLUSION

In this study, a research on a specific Guangzhou comprehensive waiting area has been made under three situations containing FCS, UCS and WCS based on field investigation. API functions are loaded into PARAMICS simulation platform in order to realize the required control strategy. From link delay index, queue length index and link average speed index, the traffic improvement effect under FCS is obviously better compared with UCS and the improvement effect will become more obvious with the increase of traffic volume. When the traffic volume is less than Q , implementing comprehensive waiting area not only cannot improve traffic operation but also worsen traffic. Conducting FCS will improve the intersection traffic operation effectively until the traffic volume is larger than Q . The UCS will improve the intersection traffic operation until the traffic volume continues to increase in $1.15Q$ - $1.4Q$. From the passing vehicle index, there is no obvious different whether to implement comprehensive waiting area or not.

Since many drivers still have not understand the driving rule of comprehensive waiting area quite, traffic administrative department needs to promote the comprehensive waiting area control strategy in order to improve the intersection traffic operation effectively when traffic volume is large.

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REFERENCES

- Li,X.S.,Jia,S.P.,Sun,H.R.(2011).“Study on the Methods of Establishing Waiting Areas for Auto-vehicles Turning Left and Going Straight at Signalized Intersections.” *Journal of Transportation Systems Engineering and Information Technology*, 1(11),194-200.
- Jie,Y.J.,Deng,W.,Wang,W. (2006) .“Study on the Layout of Left-turn Vehicles Waiting Area at Signalized Intersections.” *Journal of Highway and Transportation Research and Development*,3(23),135-138.
- Quadstone Limited. (2002).*Quadstone paramics*V4.1Programmer User, Edinburgh, Scotland, U.K.
- Quadstone Limited. (2003). *Quadstone paramics*V4.1 System Overview, Edinburgh, Scotland, U.K.
- Wang,D.H.,Li,L.L.,Cheng,Y.H.(2009).“Critical Condition for Setting LeftO turn Waiting Area.” *Journal of Highway and Transportation Research and Development*, 11(26),132-138.
- Wang,S.L.,Wang,F.,Qiu,R.H.(2009).“Traffic Impact Analysis using Microscopic Traffic Simulation Model.” *Journal of Transportation Systems Engineering and Information Technology*,9(6), 81-86.
- Yuan,H.,Ye,Y.C.(2008).“Study on Shared-parking-area Method in Traffic Organizing.” *Communications Standardization*,11,64-66.
- Zheng,W.Z.,Shi,Q.X.,Li,D.(2004).“Comparison and Evaluation of Traffic Diversion Plans Based on Microscopic Traffic Simulation by PARAMICS.” *Journal of Highway and Transportation Research and Development*,21(011),70-73.
- Zhuang,Y.,Hu,M.W.,Li,D.H.(2005).“Application of Microscopic Traffic Simulation Software PARAMICS on ITS Modeling and Evaluation.”*Journal of System Simulation*.17(7), 1655-1659.