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Evaluation of Performance of Bus Lanes on Urban Expressway Using Paramics Micro-simulation Model

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Abstract

Urban expressway, as the main skeleton of the road network, is the aorta between urban regions and urban external traffic communication, but also bears the commuter channel. It makes a large amount of traffic flow into the expressway, resulting the congestion in the expressway in many big cities, including Beijing. Taking the Beijing southwest third ring expressway for example, a simulation model was built using Paramics. The simulation model was pre-evaluated before and after the bus lanes set, and the model was post-evaluated to verify the validity of the model after the bus lanes were implemented, it has important theoretical and practical value.

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Keywords: public transport priority; bus lane; expressway; Paramics

1. Main text

Public transport priority, as the primary means to solve the problem of urban traffic congestion, has become a consensus among the traffic management department around the world. And the bus lane is set to implement effective measures for public transport priority.

The bus lane setting on the expressway can improve the efficiency of expressway traffic, reduce traffic congestion, improve urban traffic overall operating environment. Therefore, it has become an urgent problem about how to coordinate the distribution of the road resources of vehicles and buses on time and space, to ensure not only the efficient operation of the buses but also the basic smooth of the expressway.

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Currently researches focused on bus lanes setting on the main road. Amer S. Shalaby [1] used the TRANSYT-7F simulator to examine changes in performance measures of through buses and adjacent traffic following the introduction of reserved lanes in an urban arterial and examine the specific impacts on modal performance of two policy measures implemented in conjunction with lane introduction. Albert Gan [2] used the CORSIM simulation model to estimate the bus and non-bus travel speeds under various scenarios of prevailing conditions, including bus volume, non-bus volume, right-turn volume, bus stop location, bus stop density, presence of bus bay, number of bus berths, mean dwell time, green ratio, cycle length, signal offset, and number of lanes. Jepson Dal and Ferreira Luis [3] examined the typical travel time impacts of various bus priority measures to assist in the selection of appropriate treatments for particular road networks. Lu Jian [4] got the calculation method of the best bus traffic flow required using mature traffic model. And he verified the feasibility using the actual application, to provide preliminary ideas about how to evaluate the effectiveness of bus lanes.

But the bus lane suitable for expressway lacks depth study. In this paper, based on the survey data, the simulation model was pre-evaluated before and after the bus lanes set, and the model was post-evaluated to verify the validity of the model after bus lanes opened, it has important theoretical and practical value.

2. Methodology

Because of the limitation of research conditions, it can’t analysis the bus lanes with different setting conditions on the real scene. This paper studied on the effect of different forms of bus lane on traffic by microscopic traffic simulation method, basing on Paramics. Quadstone Paramics [5] is one of the top microscopic traffic simulation softwares. It supports various elements to build simulate network and show network geometric structure clearly. It also can model and simulate for transportation infrastructure, such as traffic lights, coil, roadside prompt card, parking and so on.

This paper selected the Paramics microscopic simulation model to simulate regional road network and finished the calibration of traffic model parameters. It provided a test environment for the evaluation of bus lane setting. Through the comparison and selection of evaluation index, it built the simulation model, and then analyzed the simulation results. It analyzed the impact on traffic by bus lane setting.

Beijing's third ring road, an urban expressway with 6-8 lanes, has a large bus traffic flow and density on the main road. Accordingly, this paper chose Beijing southwest third ring road from Caoqiao to Gongzhufen section and the surrounding roads of the region.

The selection of evaluation index

The main purpose of the simulation is to evaluate the effect of road traffic generated by setting generated bus lane. Therefore this study selected peak hour traffic flow, average speed and travel time of social vehicles, average speed and travel time of bus and so on as the evaluation indices, according to the Transportation Engineering [6] and Highway Capacity Manual [7].

(1) Traffic flow of social vehicles at peak hour

After setting the bus lane, there is the great impact on social vehicles due to compression of a lane. It directly affects the social vehicles traffic volume, so social vehicles traffic flow at peak hour is chosen as one of the evaluation indices.

(2) Average speed and travel time of social vehicles

After setting the bus lane, interference between the vehicles on the social lane is increased, and operational efficiency of road would be decreased. So it is chosen as one of the evaluation indices.

(3) Average speed and travel time of buses

Travel speed is an important indicator of operational efficiency of road. Buses on the bus lane and social vehicle are divided, relatively independent, so the speed of the buses should be used as one of the evaluation indices.

(4) Per capita travel time

The main purpose of setting bus lane is to ensure the travel efficiency of passenger, so per capita travel time is chosen as one of the evaluation indices.

3. Model building

3.1. The scene of simulation model

This paper conducted investigations and simulation experiments with southwest third ring road. The simulation experiment set up 3 scenes: non-bus lane, medial road bus lane and road side bus lane.

3.2. The building of simulation model

Model is built specifically including ground road (lane and speed limit), flyover, main roads, ramps, bus lanes, bus stations, bus lines and so on.

(1) Road Modeling

The main elements included: the main and auxiliary road, branch road basic modeling; linear control; road speed limit factor; level crossing, ramps, flyover and so on. As it's shown in Figure 1.

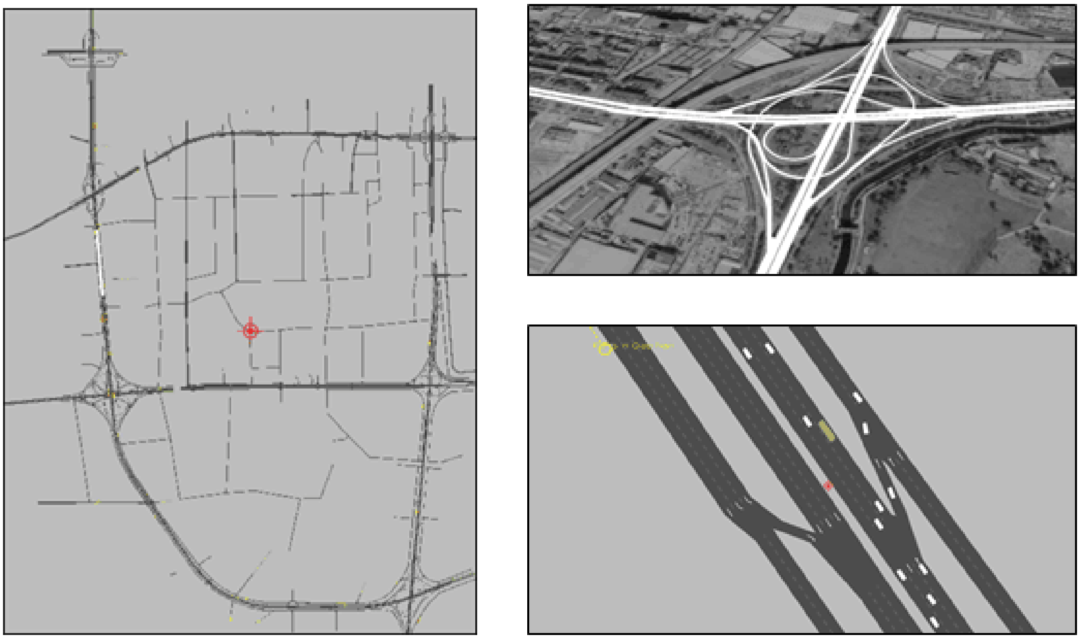

Fig. 1. The building of simulation model.

(2) Bus Lane Modeling

The main elements included: bus station, specific route (distinguish the main and auxiliary road), waiting time, departure interval, bus type, medial road bus lane and road side bus lane. As it's shown in Figure 2 and Figure 3.

3.3. The calibration of simulation model

According to the actual survey data, this paper calibrated social vehicles' OD associated with southwest third ring expressway. Based on GPS data and survey data, it calibrated buses start running data. Survey results showed that peak hour traffic flow was about 4400pcu/h on third ring road in demonstration area. According to the survey data, the model was calibrated. So model shows that the main road peak hour traffic volume is 4353pcu/h and the auxiliary road ramp flow is 300-500pcu/h while there was non-bus lane.

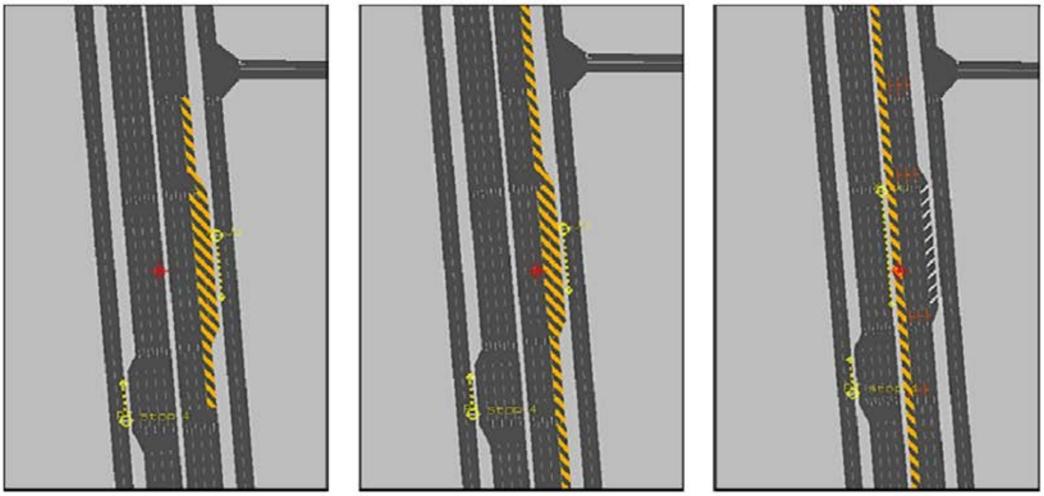

Fig. 2. The model building of non-bus lane, medial road bus lane and road side bus lane.

Fig. 3. The model building of bus lines.

4. Simulation pre-evaluation

In this paper, a preliminary evaluation is done of the program about the implement of bus lanes on the Beijing southwest third ring road, through the simulation and comparative analysis of non-bus lane, medial road bus lane and road side bus lane, using microscopic traffic simulation model. In order to study the impact of two different kinds of bus lanes form on traffic, the following is the detailed analysis of the simulation results.

(1) Average speed and travel time of buses at peak hour

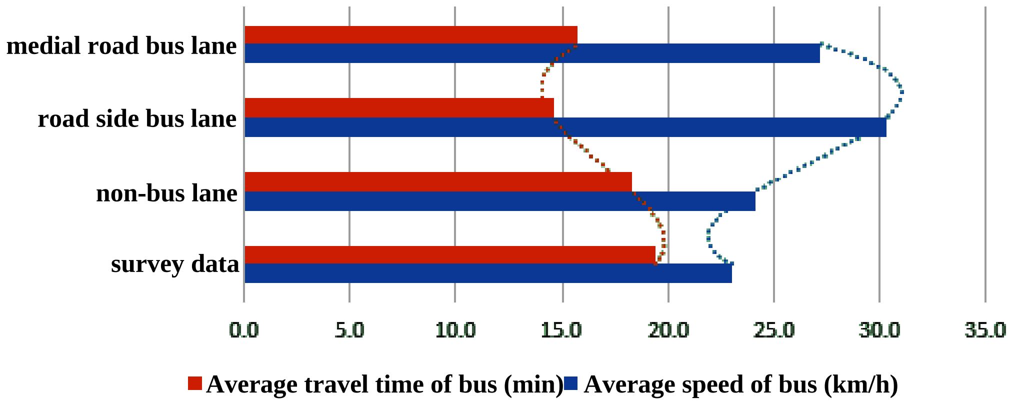

Fig. 4. Average speed and travel time of buses at peak hour.

According to the simulation result (Figure 4), it shows that the bus lanes avoid the interference of social vehicles for public transport, can significantly improve the speed of the buses and shorten the travel time. Due to the lower operating efficiency in medial road station than road side style, the average speed of buses on the medial road bus lanes is lower compared with the roadside bus lanes.

(2) Average speed and travel time of social vehicles at peak hour

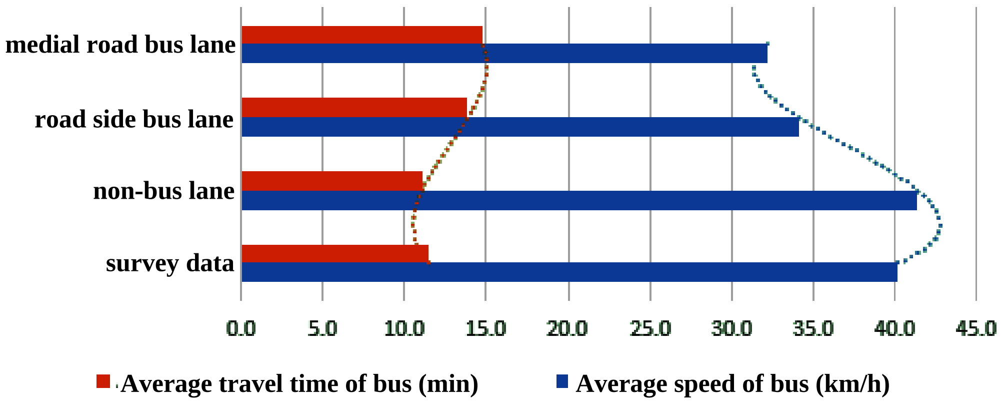

Fig. 5. Average speed and travel time of social vehicles at peak hour.

According to the simulation result (Figure 5), it shows that bus lanes are set up so that the number of lanes reduced, leading to social vehicles density increases, the speed decreases and travel time increases. The buses on the medial road bus lanes will interfere the social vehicles while in and out of the main road, leading to social vehicles speed is lower than that on the road side lanes.

(3) Traffic flow of social vehicles and per capita travel time at peak hour

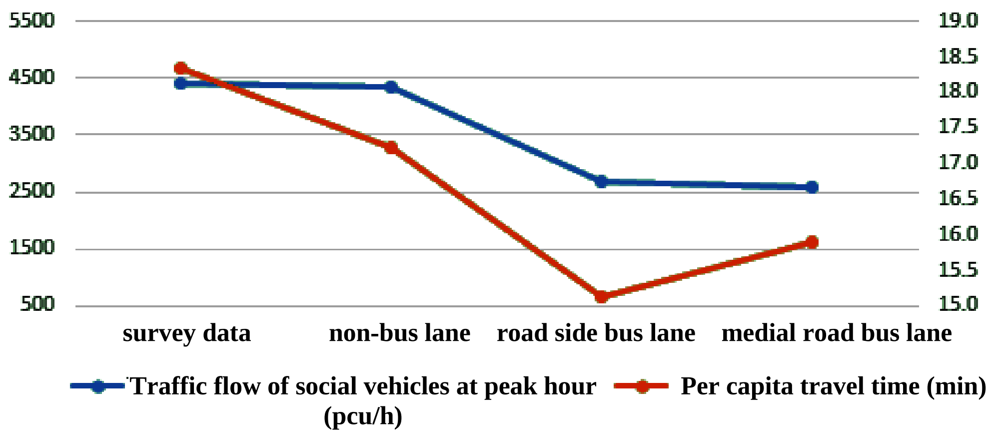

Fig. 6 Traffic flow of social vehicles and per capita travel time at peak hour

According to the simulation result (Figure 6), it shows that both forms of bus lanes will lead to social vehicle peak hour traffic volume decline, the main reason is the lanes' reduction resulting in the capacity reduced and the interference of the buses while in and out of the main road. Due to the buses on the medial road bus lanes in and out the main road, it will brings more interference with the social vehicles. However, the setting of bus lanes can significantly reduce per people travel time, increase the efficiency of the road network overall travel and effectively improve transit service levels and turnover capacity.

5. Simulation post-evaluation

The results of the simulation pre-evaluation show that bus lanes system can greatly enhance the overall liquidity of the southwest third ring expressway.

From November 30, 2014, Beijing officially opened southwest third ring expressway bus lanes from Yuquanying Bridge West to Xinxing Bridge South, with bidirectional open during peak hours. And the lanes are set at the road side. Therefore, after the bus lanes opened, it's necessary to continue to track the acquisition and post-analysis of its operation. The followings are some analyses about the comparison between the simulated data and the measured data to verify the validity of the model.

(1) Comparison of average speed between simulated and measured data

As it is shown in Figure 7, the average speed of the social vehicles actually reduced from 40.2km/h to 31.9km/h, while the average speed of the buses increased from 23.0km/h to 28.1km/h. Compared to the simulation results, the measured data is lower.

(2) Comparison of average travel time between simulated and measured data

As it is shown in Figure 8, the average travel time of the social vehicles actually increased from 11.50min to 14.56min, while the average travel time of the buses reduced from 19.46min to 15.12min. The measured data is similar with the simulation

(3) Comparison of traffic flow of social vehicles at peak hour between simulated and measured data

Traffic flow of social vehicles at peak hour actually reduced from 4400 pcu/h to 2823 pcu/h, with little difference between the simulation results.

(4) Comparison of per capita travel time between simulated and measured data

Per capita travel time actually reduced from 18.34min to 16.33min, with little difference between the simulation results, slightly higher than the simulation results.

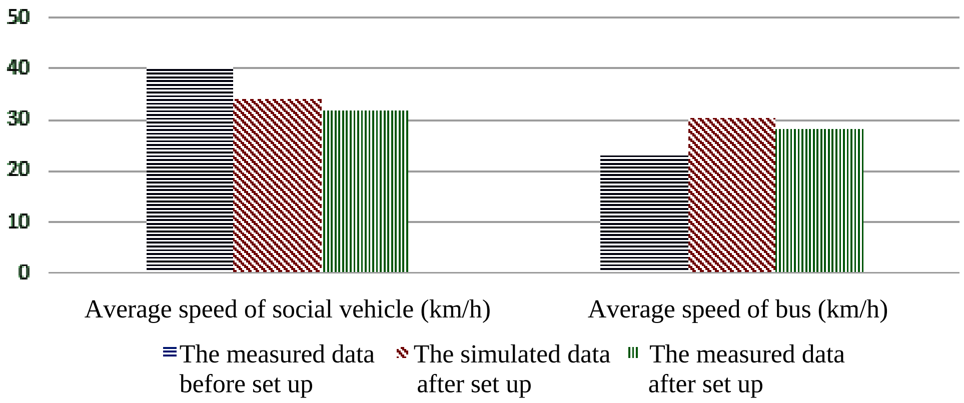

Fig. 7 Comparison of average speed between simulated and measured data

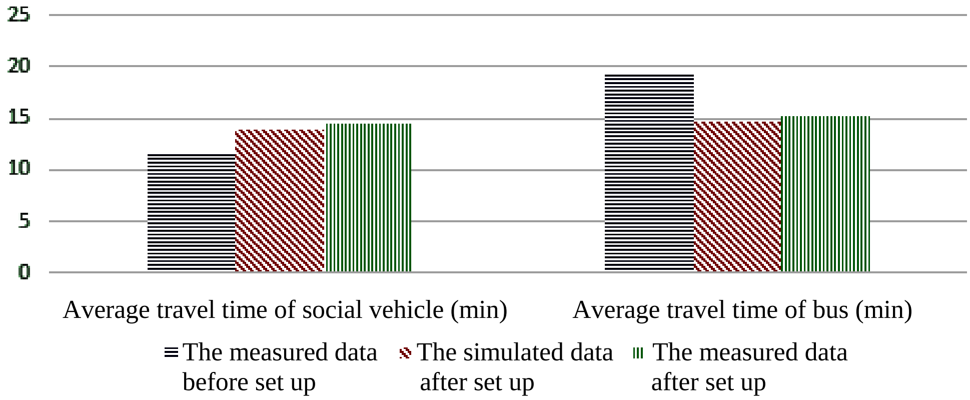

Fig. 8 Comparison of average travel time between simulated and measured data

As it can be seen from the above analyses, simulated data has error compared with the measured data, which is because the simulation model cannot be completely simulate the real situation of road network and the actual road environment factors are complex. Thus, it's necessary to calculate the relative error. Relative error is calculated as follows:

$$\text{relative error}=\left|\frac{measured\ \ data-simulated\ \ data}{measured\ \ data}\right|*100\% \qquad (1)$$

Table 1 shows the error analyses between the measured data and the simulated data. It shows that the error can be controlled within 8% between the pre-evaluation and measured data.

This also indicates that the degree of agreement between the simulation pre-evaluation and the measured data is high, that is to say, the simulation model can describe the operation of the traffic more accurately with satisfactory effect.

Field validation and comparative analysis between the results and the archived geological rock mass data both proved that this method has the advantage of high goodness of fit and satisfactory effect.

But there are still some differences between the measured data and simulated data. Bus lanes is not actually achieve the desired effect like simulation results.

Table 1. Difference between simulated data and the measured data.

Parameters	Average speed of bus km/h	Average travel time of bus min	Average speed of social vehicles km/h	Average travel time of social vehicles min	Traffic flow of social vehicles at peak hour pcu/h
The measured data before set up	23.0	19.46	40.2	11.5	4400
The simulated data after set up	30.3	14.59	34.1	13.86	2685
The measured data after set up	28.1	15.12	31.9	14.56	2533
Relative error	7.83%	3.51%	6.90%	4.81%	6.00%

6. Conclusions

Irregular driving of buses is one of the important factors affecting the traffic efficiency of expressway. Through the establishment of bus lanes to achieve the rational allocation of resources, then the traffic problem would have been alleviated. It is one of the effective solutions which is widely recognized.

In this study, the southwest third ring expressway dynamic simulation model was constructed based on Paramics. Through simulation model, there was simulation and pre-evaluation for the design of the bus lane scheme. And it analyzed the traffic situation after opening bus lanes. Through error analysis between simulated data and measured data, it indicated that pre-evaluation results obtained by simulated data and measured data after constructed could fit well. This also showed that micro-simulation models can play a nice role in the pre-evaluation in urban traffic management. At the same time, the results also showed that the bus lane could greatly improve the road capacity. Overall it could reduce traffic congestion and attract more commuters to choose public transportation. However, in the third ring road traffic environment, bus lanes simply with scope planning and design is unable to play its due effectively. Therefore, it is necessary to carry out response measures study after setting up bus lanes, realizing high performance, balanced use of bus lanes.

References

[1] Shalaby, A. S., 1999. Simulating performance impacts of bus lanes and supporting measures. Journal of transportation engineering, 125(5): 390-397.
[2] Gan, A., Yue, H., Ubaka, I., et al., 2003. Development of operational performance and decision models for arterial bus lanes. Transportation Research Record: Journal of the Transportation Research Board, 1858(1): 18-30.
[3] Jepson, D., Ferreira, L... Assessing travel time impacts of measures to enhance bus operations. Part II: Assessment criteria and main findings. Road and Transport Research: a journal of Australian and New Zealand research and practice, 2000.
[4] Lu, J., 2003. The study of install conditions of bus lane. Communications standardization,01:59-61.
[5] Council, Washington D.C.Scott Aitken, Richard Braidwood. PARAMICS Modeller’s Version 6.93 User Guide. Edinburg: Quadstone Limited, 2014.
[6] Ren, F.T, Liu, X.M., Rong, J.. Transportation Engineering.Beijing: China Communications Press, 2003.
[7] Highway Capacity Manual: Transportation Research Board, National Research, 2000.