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Solutions to Traffic Jam on East Road of Beijing Jiaotong University in Rush Hours Based on Analogue Simulation

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ABSTRACT: Based on the simulation theory and method, this paper establishes a status analogue simulation model in peak hours, realizes an effective assessment on the road, finds out bottlenecks to improve the level of road services and puts forward the corresponding road improvement program. This paper simulates the improvement program by the use of VISSIM simulation model, and verifies the improvement effect of four programs and carries out promotion. The research obtains an effective method of solving the problem of jam on the sub-arterial road: It needs to set up by-pass and control over traffic flow of the by-pass, and give full play to the role of by-pass in city.

Keywords: rush hours; congestion; analogue simulation; optimization

1 RESEARCH BACKGROUND

At present, the optimization research of road traffic mainly focuses on intersections with larger traffic volume, more complicate traffic situation and larger scale [1]. The road simulation software is mostly used for adjustment of intersection lane settings and intervals of signal lamp, so as to optimize the traffic capacity of the intersection [2-3]. The research is relatively less on the bi-directional two-lane roads with strong fluctuation of traffic flow and human flow and more on roadside passageways, frequent violation of vehicles and pedestrians. Such roads are mostly concentrated on the school, centralized offices and other places with obvious tidal phenomena of people and traffic flow [4].

To explore the solutions to the problem of jam on the sub-arterial road, we take the east road of Beijing Jiaotong University as an example, and this paper verifies the improvement program and researches application conditions of other sub-arterial roads. On the east road of Beijing Jiaotong University, human flow and traffic flow may increase sharply in a short term in the morning and evening rush hours in the road segment of Beijing Jiaotong University. Coexistence of people and vehicles, traffic jam, non-guarantee for the safety of pedestrians and vehicles and many other problems are caused by illegal roadside parking, forcible changing lanes by some vehicles, jaywalking and other reasons. In addition, some merchants break rules and occupy roads to operate business. Such situation intensifies the traffic jam on this road segment, and even affects the smoothness of nearby road to a certain extent.

2 ANALYSIS OF CONGESTION REASON

1) Issues of roadside parking and street pedlar

In the road segment, the vast majority of vehicles are parked on the roadside delineated berth. In the non-rush hours, such practice can adapt to the needs of the road traffic; but in the morning and evening rush hours, the traffic flow is large, which will have a greater impact on the traffic. However, the issue of street pedlar mainly exists in summer evening. Few pedlars put the stalls in the crowded intersection or roadside, which may cause some obstacles to the normal operation of road traffic.

2) Students jaywalking in particular rush hours

Some students jaywalk at recess time, crossing the traffic flow on the east road of Beijing Jiaotong University. Vehicles intermittently stop and queue to avoid running into the students.

3) Analysis of cross-flow line

The most vulnerable jam in this road segment is between the southeast door of Beijing Jiaotong University and the intersection of the family area. In this road segment, the road traffic flow has grade crossing line and priority-type crossing, which is prone to produce conflict.

3 ANALYSIS AND SIMULATION OF TRAFFIC FLOW

The data with the time interval of ten minutes are investigated and processed. The four intersections in the measured road segment are numbered as 1, 2, 3 and 4. The data measured in each intersection are shown in Figure 1. *L* represents the traffic flow of each flow line, *S* represents the up direction, and *X* represents the down direction. After processing the data, the number of turning left and right in each direction roughly has the following ratio, which is shown in Table 1. The simulation time is divided into four time periods, with each time period of 600s. After

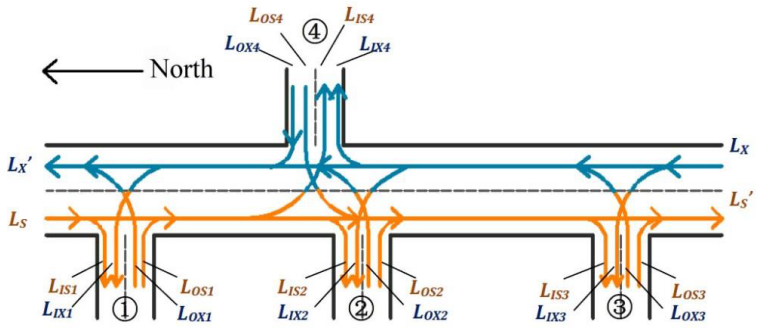

Figure 1. Schematic diagram of traffic flow line

Table 1. Ratio of turning left and right in each direction (unit: vehicle)

L_X=100	L_{IX1}=1	L_{IX4}=2	L_{IX2}=9	L_{IX3}=1	L_X'=87
LS=100	L_{IS3}=1	L_{IS2}=9	L_{IS4}=2	L_{IS1}=2	L_S'=86

Table 2. Ratio of turning left and right in each direction (unit: vehicle)

Entrance	Vehicle model	Time period 1	Time period 2	Time period 3	Time period 4
Sidaokou	Sedan car	91%	91%	91%	90%
	Middle-sized vehicle	1%	1%	1%	1%
	Bus	8%	8%	8%	9%
Baijin	Sedan car	90%	93%	88%	90%
	Middle-sized vehicle	1%	1%	1%	1%
	Bus	9%	6%	11%	9%
Academy of Railway Science	Sedan car	100%	100%	100%	100%
Southeast door	Sedan car	100%	95%	95%	96%
	Bus	-	5%	5%	4%
School	Sedan car	100%	97%	96%	100%
	Bus	-	3%	4%	-
East door	Sedan car	95%	95%	95%	95%
	Bus	5%	5%	5%	5%

processing of data, the ratio of output vehicles in each intersection in each time period is shown in Table 2.

According to the preliminary analysis and summary of driving mode of the road motor vehicles, this paper carries out simulation analysis of driving status in the measured road segment of the east road of Beijing Jiaotong University by the use of VISSIM analogue simulation software, and finds out that the access lines of motor vehicles in the area of east door and southeast door of Beijing Jiaotong University and opposite intersection of school have many intersections, which are not conducive to the smooth traffic flow. Such segment is the most congested road in this research.

4 IMPROVEMENT PROGRAM

4.1 *Auxiliary road increased in campus*

Program 1 proposes to establish a new channel between the car wash room of Beijing Jiaotong University and school infirmary, and to transform the southeast door into a one-way vehicle entrance and the east door into a one-way vehicle exit. The program can achieve linking with roads in campus, simplify the function of each entrance and exit, and reduce intersections of traffic flow line, so as to reduce waiting and standing time of vehicles and facilitate the vehicle traffic. The comparison between the flow line intersection status of the selected road segment and the auxiliary road increased is shown in Figure 2.

After renovation of program 1, the flow line intersections are decreased from the original 28 points to 16 points, with a decreasing number of 12. Moreover, in the dense areas of flow line intersections, that is, in a small area of southeast door and intersection of the school, the flow line intersections are decreased from the original 16 points to 11points. Various factors considered by the drivers in the decision-making process of turning decrease, so it accelerates vehicle traf-

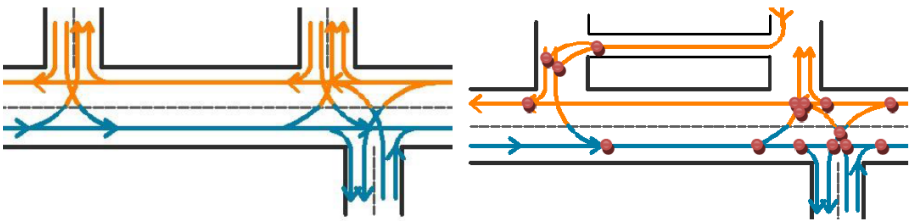

Figure 2. Schematic diagram of flow line intersection of the auxiliary road increased

fic in this region and reduces bottleneck burden. However, to increase roads in campus spends much money and involves in demolition and other issues, which requires cautious choice.

4.2 *Reconstruction of original road lane*

The program 2 strictly regulates illegal roadside parking behavior, clears roads, redistributes the structure of road lanes, and transforms part of original two-lane roads into three-lane roads.

The east door of Beijing Jiaotong University is closer to the southeast door, and the southeast door is small. Relatively speaking, the use degree of two entrances is different. The east door is almost vacant, and the southeast door is prone to be jam in the morning and evening rush hours. In addition, the road congestion is mainly concentrated on one side near Beijing Jiaotong University. Therefore, the side which is closer to Beijing Jiaotong University is considered to be divided into two lanes. It increases the conflict points to some extent, but the advantage is to increase the lanes and the vehicle traffic capacity in the region, and it also reduces the impact of vehicles turning a corner on the vehicles going straight, and accelerates the speed of vehicle traffic.

The measure of the whole program only involves in road reconstruction, with small work amount. It basically does not involve in the interests of others. The program 1 has a higher feasibility and it is economical. The improved traffic flow lines are shown in Figure 3:

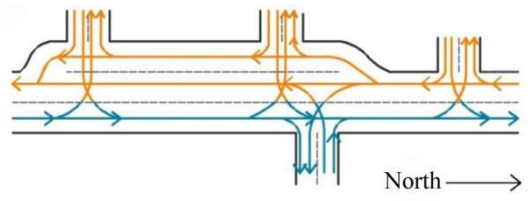

Figure 3. Schematic diagram of flow line intersections after increasing lanes

4.3 *Signal lamp timing of changing the selected road segment*

The investigation shows that the phase position of the traffic lights in front of the family area and the traffic lights in Baijin intersection fails to interact in the time, causing that the traffic flow going straight on the east road of Beijing Jiaotong University produces a greater impact on the traffic flow entered from the entrance and exit of the school. In the case of continuous traffic flow going straight, the vehicles entered from other entrances into the east road of Beijing Jiaotong University requires to wait for a long time.

As shown in Figure 4, if the timing of traffic lights and setting of phase position are improved, there is no traffic flow going straight in the area from the school to Yifu door (in the green area of Figure 5) within a certain time, so as to provide enough turnaround time and space for vehicles in each entrance and exit, and relieve jams as much as possible under the premise of reducing traffic flow going straight.

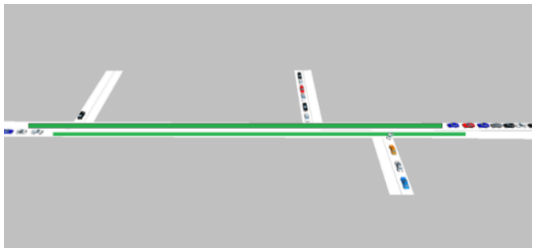

Figure 4. Idea diagram of program 4

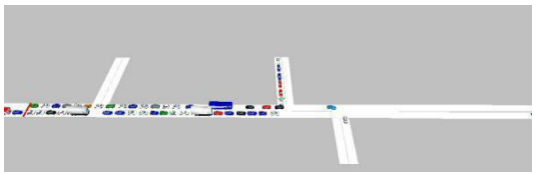

Figure 5. Schematic diagram of jam

However, after the actual simulation, we may find that after the adjustment of timing of traffic lights and change of phase position on both sides, there is no significant improvement on jam. Through the analysis, due to the difference in the number of entrance and exit on the east side and west side of east road of Beijing Jiaotong University and a big gap in the traffic

flow, the time for vehicles to pass through this area has a larger randomness, resulting in difficulty in formation of expected vehicle-free area only through the change of timing of traffic lights and change of phase position, as shown in Figure 5.

4.4 *Comparative analysis of optimization program and status simulated data*

1) Comparison of travel time

The travel time is overall for vehicles to pass through the road segment, which is closely related with the road traffic situation. Through the transformation, the travel time is mostly reduced, and the optimization program has a good effect on improving the travel time.

In the program 1, the travel time from Baijin to Sidaokou, from east door to Sidaokou, from southeast door to Sidaokou, and from Baijin to southeast door has a greater reduction. Therefore, in the program 1, the methods of increasing road segments and stipulating driving direction will reduce and transfer the intersections. Such program is effective.

In the program 2, the travel time from Sidaokou to Baijin and from school to Baijin does not have any change. It indicates that the program 2 does not improve nor increase the lane direction. For the increasing lane direction, the program 2 dismantles and disperses the flow line intersections gathered in the lane, so that the traffic situation from Baijin to Sidaokou, from southeast door to Sidaokou, and from Baijin to southeast door has significant improvement.

2) Comparison of delay time

The delay time is greater than the time of smooth passing produced by the impact of a variety of factors during driving, which directly reflects the smooth degree of road. Through adjustment of optimization program, the delay time is reduced. In the program 1, the decrease extent is up to 87.1%; in the program 2, the decrease extent is up to 75.6%. But in the direction from Sidaokou to Baijin, due to the increasing traffic flow, the delay time produced has a slight increase. In the status simulation, the level of time delay is high. Such situation is particularly obvious on the direction from east door to Sidaokou and from southeast door to Sidaokou. Therefore, the situation of the status traffic road is worse.

The program 1 can reduce delay time and optimize road conditions, so as to drive vehicle smoothly and greatly reduce start-stop. The program 2 can also reduce delay time, but the decrease degree from the east door to Sidaokou is small. Therefore, after increasing two lanes along up direction, one flow line intersection starting from the east door, passing through the up lane and arriving at the opposite lane is changed into two intersections, resulting in the decrease in smoothness of driving vehicle and high delay.

3) Comparison of the percentage of delay time to travel time

The percentage of delay time to travel time represents the proportion of delay time in driving. In the assessment of road smoothness, a low percentage of delay time to travel time represents a relatively smooth road. For the program 1, the percentage of delay time along the direction from Baijin to Sidaokou has an obvious decrease, that is, the road smoothness degree of the direction from Baijin to Sidaokou has a larger improvement than that before the optimization; for the program 2, through increasing the road segments, the road smoothness degree can greatly increase, thus reducing the percentage of status. Compared with the program 1, the decrease degree is small.

4) Comparison of occupancy and number of passing vehicles

The program 1 and program 2 have road segments transformed, so the comparative analysis is given to the data corresponding to the original road segment and the data corresponding to the status in the program 1 and the program 2.

As shown in Figure 6, in the program 1, the number of passing vehicles in the location of Number 1, 2, 5, 6, 7 and 8 is greater than the status. Meanwhile, from the broken line in Figure 7, the occupancy in the program 1 is greater than the status in the location of Number 6. Therefore, through optimization by the program 1, the number of passing vehicles increases, while the occupancy decreases. More vehicles can pass thorough the road section in the same time period.

In the optimization program 2, the number of passing vehicles in the location of Numbers 1 and 2 greatly increases. In the location of Number 2, the occupancy sharply increases, which indicates that the location of Number 2 is more congested. In the location of Number 3, the number of passing vehicles decreases. It maybe because the lane along the direction from Sidaokou to Baijin increases after increasing the lane and the vehicle passing capacity greatly improves, causing the passing capacity of one lane to decrease, which is consistent with the fact.

5) Comparison of average queue length

The queue length reflects the service level of the selected road segment to a certain extent. The longer the queue length is, the lower the service level is. Figure 8 and further analysis of the data of queue length show that, for the program 1, the average queue length of all other measuring points greatly decreases except for the measuring point 3 with the maximum reduction amount of 100% and an average reduction of 88.04%, indicating that through optimization of program 1, the service level of the selected road greatly increases; for the program 2, except for the measuring points 4 and 5, the average queue length of all other measuring points also greatly decreases with the maximum reduction amount of 74.65% and an average reduction of 50.50%, indicating that through optimization of program 2, the service level of the selected road also greatly increases.

Through the above analysis, the program 1 and program 2 have certain optimization effects, that is, the improvement of road service level. However, viewing from the number and level of optimization

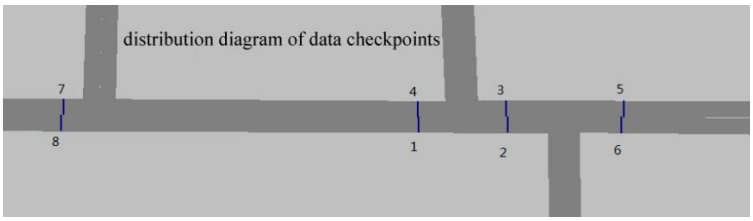

Figure 6. Schematic diagram of check point labeling in status simulation data

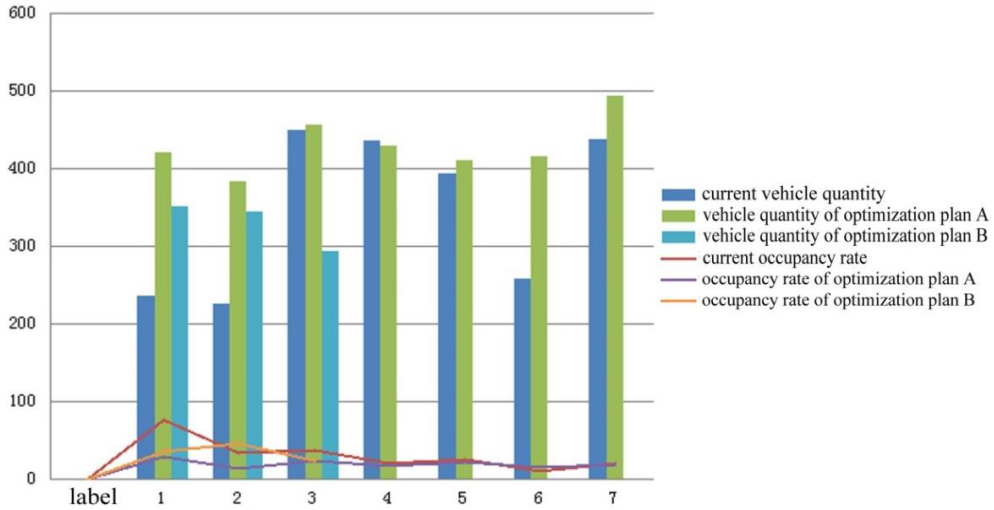

Figure 7. Comparison chart of occupancy and number of vehicles access

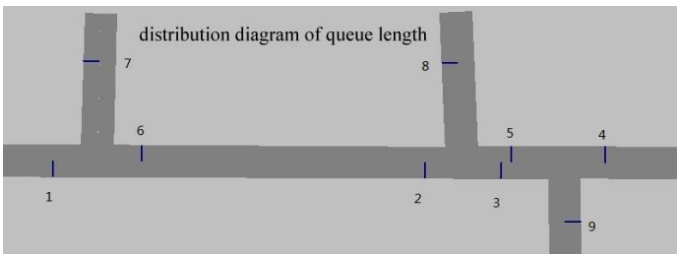

Figure 8. Distribution diagram of check point in average queue length

through data comparison, the program 1 is better than the program 2.

5 CONCLUSION

5.1 *Solutions to optimization of east road of Beijing Jiaotong University*

Through analogue simulation and data analysis of several optimization programs in Chapter IV, the improvement effect of program 1 and program 2 is more prominent. Next, the comparative analysis focuses on the program 1 and the program 2, which is shown in Table 3.

In summary, the program 1 is selected to repair roads in campus and fix the directions of entrance and exit, so as to achieve the purpose of relieving traffic jams.

5.2 *Promotion of optimization model*

The problems of traffic jam on east road of Beijing Jiaotong University have a certain representative in essence. The features of such road are summarized as follows:

1) Connect with main trunk road, which is close to large-scale public places with a large traffic volume, such as hotels, business centers and so on;

2) Connect with main trunk road with heavy jam in

Table 3. Comparative analysis of program 1 and program 2

Program	1	2
Advantages	Travel time shortens and the shortening proportion is 48.66%; Delay time shortens and the shortening proportion is 58.83%; The ratio of delay time accounting for the total travel time decreases, which is 42.06%; The average queue length decreases to 59.11%.	Travel time shortens and the shortening proportion is 38.75%; Delay time shortens and the shortening proportion is 45.82%; The ratio of delay time accounting for the total travel time decreases, which is 58.22%; The average queue length decreases to 19.42%.
Disadvantages	To newly build by-pass, it is necessary to dismantle car wash room of Beijing Jiaotong University, but the construction cost is high.	To widen road, it is necessary to dispose the steps near the house of Beijing Jiaotong University, but there are many involved interests, inconvenient coordination and high time cost.

the morning and evening rush hours;

3) Be close to the school with complicate commuting and passenger flow and intersected with traffic flow, bicycle flow and human flow, with complicate traffic situation;

4) Be close to public places and residential areas without serious phenomena of on-road parking and on-road business, resulting in the traffic jam to a large extent.

Such road is equivalent to an artery in the whole road network, which plays a role of connecting with the main artery and blood capillary. However, the function of the entire circulatory system largely relies on suitable ratio of three kinds of vessels, that is, the suitable ratio of the arterial road, the sub-arterial road and the by-pass.

Through comparison of several simulation programs, the program 1 has the best effect. Through increasing the auxiliary road to achieve the purpose of increasing the proportion of by-pass, the measures of dispersing the traffic flow on the sub-arterial road and fixing the direction of entrance and exit in the large-scale public places are adopted to achieve the purpose of relieving the traffic jam. Therefore, the methods of relieving road congestion are as follows:

1) To increase side roads in the area is prone to the conflict of traffic flow, increase the proportion of by-pass, and really play the role of relieving jam;

2) To simplify the traffic flow through fixing the direction of entrance and exit in large-scale residential areas and public spaces with many entrances and exits, and reduce the conflict point of the traffic flow.

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