Research on Optimization of Speed Limit Setting of Deceleration Zone At U-Shaped Left-Turn Three-Road Intersection

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Abstract. Intersection is a very important part of the road system. It is the concentrated part of all kinds of road traffic and one of the places where accidents are most likely to occur. Therefore, the design and management of intersection is very important for urban traffic flow and safety. By combining VISSIM simulation software with SSAM software and MOVES emission model, this paper uses traffic simulation software VISSIM to simulate 125 schemes composed of three factors : different traffic composition, road speed limit and vehicle deceleration through speed bumps. The optimization of speed limit at unsignalized U-turn left-turn intersections is studied from three aspects : delay, conflict and emission. The results show that the delay is the smallest when the speed limit is 0 %. From the perspective of driving safety, the traffic conflict rate is the smallest when the speed limit is 30 %. From the perspective of emission, when the speed limit is 10 %, the vehicle exhaust emission is relatively small. From the comprehensive analysis of the three research indicators, it is concluded that the reasonable speed limit scheme for the speed limit of the speed reduction zone at the U-shaped left-turn intersection without signal control is to reduce the road speed limit by 10 %.

Keywords: U-turn ; Reducer belt ;Ttraffic simulation ; VISSIM model ; MOVES model ; Vehicle exhaust emissions

1 INTRODUCTION

China 's domestic urban road vehicles often turn around at intersections and road sections in advance. It is generally believed that the setting of turning lanes at intersections has the greatest impact on the traffic efficiency and traffic safety of intersections. Vehicles that need to turn around should turn around at the road section or far lead in front of the intersection as far as possible. In short, the early turning of the road section is an effective measure to improve the efficiency of road traffic. The purpose of this paper is to demonstrate whether the setting of speed bumps at intersections with unconventional central dividers can reduce the incidence of traffic accidents and improve the efficiency of intersection traffic ; whether it can fundamentally reduce the frequent switching of

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operating conditions such as acceleration and deceleration of motor vehicles, and whether it can reduce motor vehicle exhaust emissions and improve fuel efficiency to a certain extent.

In the research and practice of setting U-turn speed bumps in unconventional central dividers, foreign countries have relatively perfect research results. The research results of Usama Elrawy Shahdah, Abdelhalim Azamb and others on setting speed bumps at U-turn left-turn three-way intersections also show that regardless of the hump position of the speed bumps, the hump speed of 5.0km / h significantly increases the average delay of the intersection by 109 % -448 %, and seriously increases the traffic conflict. When the hump speed is 20.0km / h, according to the traffic conditions, the average delay increases by 2 % -6 %. In addition, a 20km / h hump may reduce traffic conflicts by about 11 % -20 %[1]. In recent years, many researchers such as Frey[2], Younglove[3], Davis[4] have studied the modeling method based on VSP variables. Typical vehicle emission models such as MOVES model and IVE model, which are widely used, are also the main calculation models using vehicle specific power VSP as the emission module.In addition, at present, there are many researches on the scientific research results of setting speed bumps on roads in China.Li Qilang, Liu Jun and others ' research on the impact of speed bumps on pollutant emissions in the working area shows that in the road section with less vehicle traffic, reasonable setting of speed bumps can effectively ensure traffic safety, and at the same time reduce pollutant emissions due to reduced vehicle speed[5] .

This paper is mainly based on the operating characteristics of the U-shaped three-way intersection of the unconventional central divider of urban roads. Based on the scientific research results of the existing U-shaped left-turn traffic design, the deceleration zone scheme at the intersection is studied. Since the U-shaped left-turn three-way intersection has not been applied in practice, in order to analyze and evaluate the situation of setting the deceleration zone at the intersection, VISSIM software is used to simulate and analyze the intersection before and after setting the deceleration zone under the same traffic composition and urban road speed limit conditions. The average delay extracted by the microscopic simulation model VISSIM is used as a measure of traffic efficiency, the number of intersection conflicts extracted by the safety assessment model SSAM is used as a measure of traffic safety, and the exhaust emissions extracted by the vehicle exhaust emission model based on VSP distribution is used as a measure of traffic environment assessment. By means of charts and line charts, the relevant evaluation index values of each reducer belt scheme are expressed. Through comparative analysis, the relationship between the three factors is given, and the optimal reducer belt scheme is finally selected, See **Fig. 1**

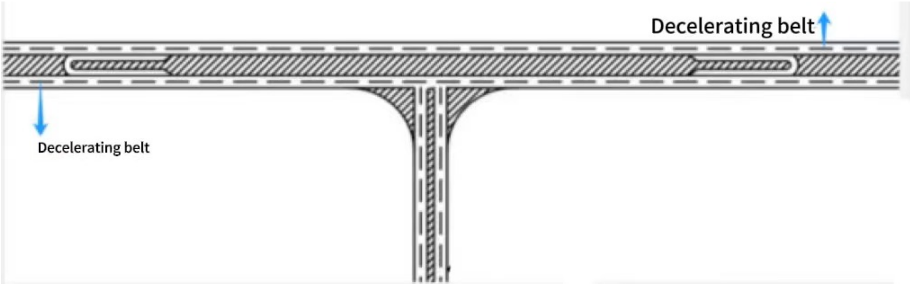

Fig. 1. Intersection diagram

2 RESEARCH CONTENT

When considering the indicators, this paper considers various factors such as traffic safety, environmental conditions and traffic efficiency, and selects different evaluation objectives to correspond to different evaluation directions. Therefore, it is necessary to comprehensively consider various influencing factors to make the design evaluation index reasonable, normative and representative. However, in the actual specific operation, it is necessary to compare and analyze the various indicators and select the more important indicators.

This paper mainly uses the microscopic simulation model VISSIM to explore the optimization of setting the deceleration zone at the intersection of the U-shaped left-turn three roads under different traffic composition conditions, different road speed limits, and speed limit of the deceleration zone, See **Table 1**

Table 1. Variable setting of each factor

Change of urban road speed limit	Changes in traffic composition	Speed limit change of deceleration belt
20km/h	Truck crash rate5%	Reduce road speed limits0%
30km/h	Truck crash rate10%	Reduce road speed limits10%
40km/h	Truck crash rate15%	Reduce road speed limits20%
50km/h	Truck crash rate20%	Reduce road speed limits30%
60km/h	Truck crash rate25%	Reduce road speed limits40%

Using the control variable method, there will be 125 results in theory. For example, when the road limit speed is 40km / h, the speed of the vehicle after passing the speed bump is 40,36,32,28,24km / h, and the relative flow of the vehicle is changed at this time. The relative flow of the truck is 5 %, 10 %, 15 %, 20 %, 25 %, a total of 25 results.

In summary, 125 kinds of simulation results are analyzed and compared, and each scheme is evaluated from the indexes of delay, conflict and emission. The optimization of the scheme of setting the deceleration belt at the U-shaped left-turn three-fork of the very central separation belt is studied.

3 RESEARCH MODEL

At the opening of the central isolation belt, the turning vehicle needs to slow down and stop, waiting for the pluggable gap in the straight traffic flow of the opposite lane to turn around[6],See **Fig. 2**

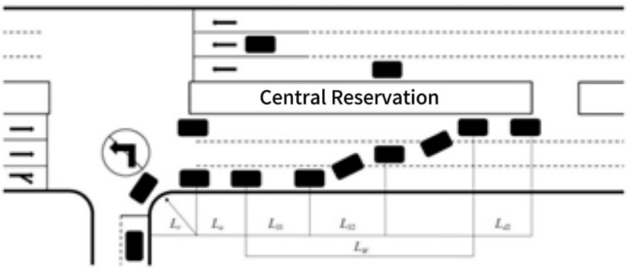

Fig. 2. U-shaped left turn flow chart.

(1) Urban road three fork intersection, two-way four-lane road, road width of 3.5m ; the width of the central separation zone is 15 m.

The distance between the intersection and the central separation zone is 200 m. The distance between the speed bump and the intersection is 20 m ; the width of the U-bend is 12.5 m, and the length of the storage lane is 50 m.

(2) Set the flow of each section. The total flow of the east-west inlet is 1250pcu / h, and the ratio of traffic flow in each direction is fixed at 7 : 2 : 1. The total flow of the south entrance lane is fixed at 600pcu / h, and the ratio of traffic flow in all directions is fixed at 5 : 5.

4 DATA ANALYSIS

4.1 Delay Analysis

With the help of the average delay index output by the microscopic simulation model VISSIM, the traffic efficiency of setting the deceleration zone at the intersection is evaluated, and the relationship between the deceleration of the deceleration zone and the above two factors is obtained. The U-shaped intersection is simulated with the speed limit of the deceleration zone from 0 % to 40 %, and the traffic delay is shown as follows :

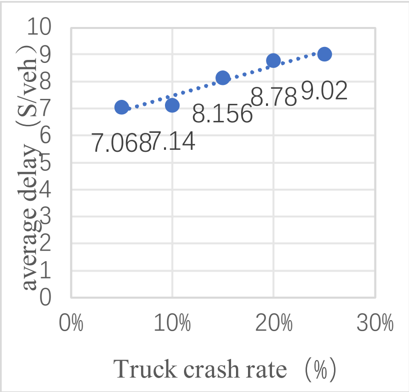

Fig. 3. Intersection delay diagram of different truck incorporation rate.

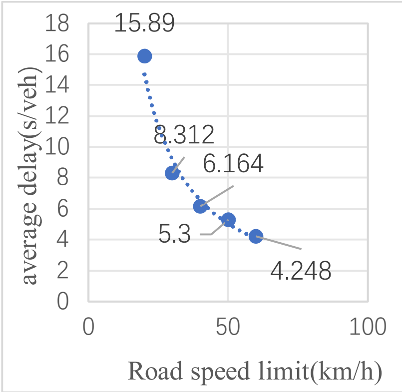

Fig. 4. Delay diagram of different road speed limit intersection.

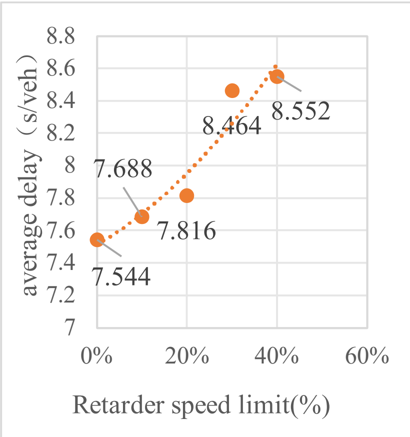

Fig. 5. Intersection delay diagram under different speed limit of deceleration zone.

The average delay of the vehicle will increase with the change of the truck incorporation rate from 5 % to 25 % (see **Fig. 3**). For different urban road speed limits, the average vehicle delay shows a decreasing trend. The smaller the urban road speed limit, the less obvious the advantage of setting speed bumps at intersections (see **Fig. 4**). In terms of optimizing the traffic efficiency of U-shaped intersections, the advantage of reducing the road speed limit by 0 % in the speed limit scheme of the deceleration zone is more obvious, See **Fig. 5**

4.2 Conflict Analysis

Traffic conflict was first proposed by Perkins R et al[7]. Amudsen et al[8].defined traffic conflicts.

Using SSAM software to analyze the trajectory files in VISSIM, the number of traffic conflicts can be obtained.

It can be seen from **Fig. 6** that when the speed limit of urban roads is constant, the average number of traffic conflicts in the setting of speed bumps increases with the increase of truck incorporation rate. When the traffic composition is fixed, the average conflict of the deceleration zone scheme decreases with the increase of the urban road speed limit. When the road speed limit is 60km / h, the number of conflicts at the intersection is the least (see **Fig. 7**). From **Fig. 8**, it can be seen that under the same traffic composition conditions, the average vehicle conflict at the intersection decreases first and then increases with the reduction of road speed limit 0 % -40 % in the speed bump scheme, and the average vehicle conflict is the least when the road speed limit is reduced by 30 %.

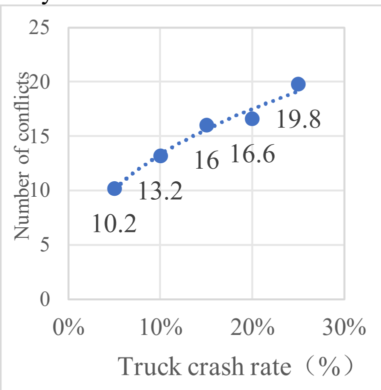

Fig. 6. The relationship between the truck incorporation rate and the number of intersection conflicts under the speed bump scheme.

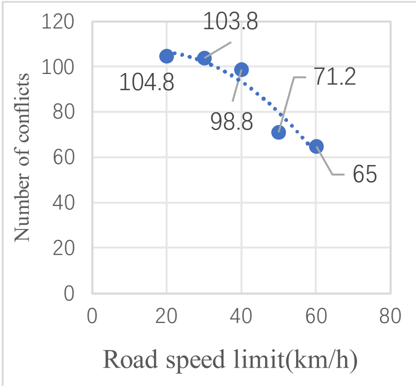

Fig. 7. Road speed limit and intersection conflict number diagram under speed bump scheme.

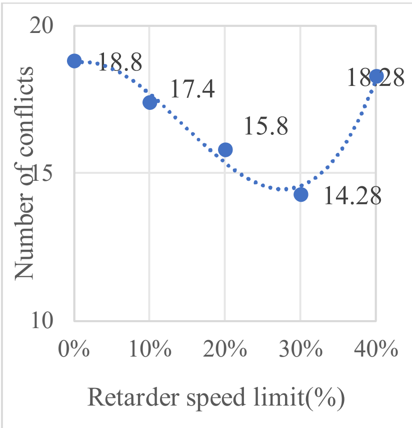

Fig. 8. Relationship diagram of intersection conflict number with speed limit of deceleration zone.

4.3 Exhaust Emission Analysis

The relevant parameters of cars and trucks are different. Therefore, the final calculation formulas of VSP are also different[9]. The formulas are as follows :

$$VSP_{LDV} = v[1.1a+0.132] + 0.000302v^3 \quad (1)$$

$$VSP_{HDV} = v[a + 0\text{。}09199] + 0.000169v^3 \quad (2)$$

v:real-time velocity(m/s),a:Real-time acceleration(m/s^2)

In this paper, the vehicle emission calculation platform is used to calculate the vehicle emission inventory at the intersection, and the CO emission inventory is analyzed to evaluate the scheme of setting the deceleration zone at the intersection.

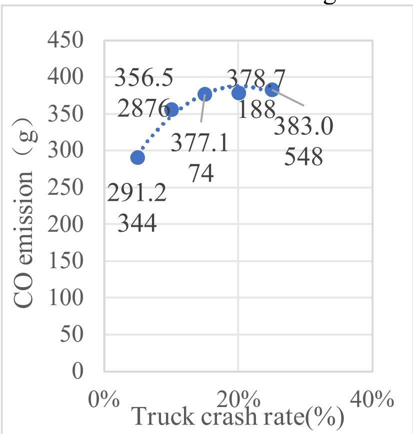

Fig. 9. The CO emission map under different truck incorporation rates.

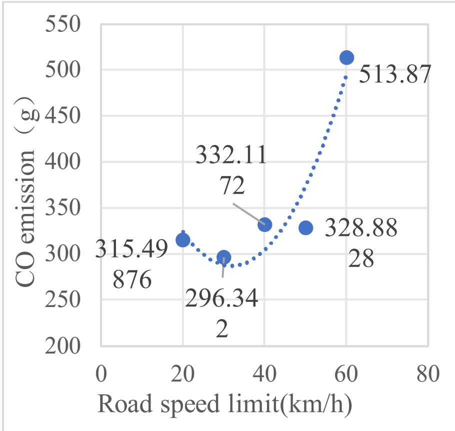

Fig. 10. CO emission map under different road speed limits.

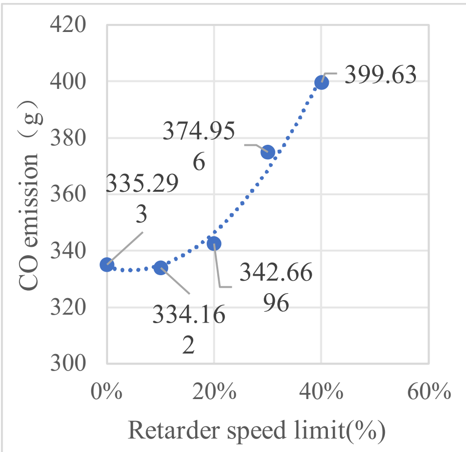

Fig. 11. Change diagram of CO emission at intersection with speed limit of deceleration zone.

The results show that when the urban road speed limit is constant, the average CO emission of the speed bump scheme increases linearly with the increase of the truck incorporation rate (see **Fig. 9**). When the traffic composition is fixed, the CO emission of the deceleration zone scheme increases with the decrease of the urban road speed limit, and the CO emission of the intersection is the least under the road speed limit of 30km / h (see **Fig. 10**). After setting the speed bump scheme, when the road speed limit is reduced by 10 % in the speed bump scheme, the pollutant emission is the least (see **Fig. 11**).

5 CONCLUSION

From the above analysis, it can be concluded that from the perspective of delay and conflict, no matter which one of the speed bump schemes is selected, the changes of conflict and delay are relatively small. In the evaluation of different schemes, we will analyze from different evaluation indicators. Because the conflict and delay changes are relatively small, from the perspective of vehicle exhaust emissions, reducing the road speed limit by 10 % in the speed bump scheme is the best speed limit scheme. In this paper, the traffic composition is only for the analysis and evaluation of traffic conflicts, delays and emissions between cars and trucks, without considering the impact of non-motor vehicles and pedestrians on intersections. The above factors should be considered in the future research, so as to make the traffic flow of urban road three forks more reasonable, efficient and orderly. This article is only a macro analysis of delay, conflict, and emission indicators. In subsequent studies, sensitivity analysis should be performed on different evaluation indicators to select the best research plan. In addition, the application of the speed bump scheme proposed in this paper in actual traffic planning should be further explored.

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