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The Application of Traffic Simulation Technology in Traffic Transportation System

--A Case Study on the Construction Area Conflict of One-way Highway

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Abstract

For the study of traffic simulation and SSAM method applied in the field of traffic safety evaluation, a traffic simulation model was established by taking the closure one-lane work zone of expressway as an example, and the vehicle track files, which output from simulation model, was analyzed by using SSAM method. The traffic conflicts and traffic safety conditions of work zone were evaluated according to the SSAM model related index parameters and the number of conflicts. This paper analyzed the traffic characteristics of the one-lane closure work zone based on the data of field survey in the freeway work zone. The vehicle lane changing model and the following model based on the work zone were calibrated. The output files of SSAM model for vehicle trajectory were analyzed, the results showed that the tested work zone produced a total of 16 traffic conflicts within the duration of simulation, all of which were rear-end collisions. The combination of traffic simulation and SSAM method can evaluate the traffic safety effectively, and the results are obvious without a lot of traffic accident history data.

Keywords

One-lane closed work zone, Traffic conflict, Traffic Safety, Traffic Simulation, SSAM method.

1. Introduction

By the end of 2018, the total length of Chinese national highways was 4,846,500 km, an increase of 73,000 km over the previous year [1]. The rapid growth of the expressway mileage has promoted the rapid development of our economy, but economic development is relatively more than the freeway traffic growth expected amount of planning, lead to greatly reduces the service life of the highway, highway pavements early ageing and damaged, greatly reduce the service level of driving, can't meet the increasing traffic demand. In addition, after expressway operation for a certain period of time, it is necessary to maintain local sections or repair damaged roads to ensure the use quality and service level of the expressway. Thus, expressway construction area has become an important part of the expressway system.

Our country highway construction area traffic accident file content is not completed, lack of historical traffic accident data samples, the actual work hard to the macro indicators based on traffic accident history data statistics and analysis on the traffic safety evaluation, and the traffic conflict acquisition method is time consuming, cost large and high precision and accuracy of the data requirements. Therefore, this article mainly through the study of the data collection work of highway construction area, starting from the traffic characteristic of construction area, the study of the characteristics of the elements of highway traffic and the mutual relation, using the method of traffic simulation technology

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and alternative accidents to traffic conflict risk analysis of construction area, make people more intuitive understanding of the potential risk of highway construction area, so as to formulate corresponding management preventive measures, in order to reduce highway construction area of the risk of driving and traffic hidden trouble, reduce the number of traffic accidents, improve the level of security services.

2. Study on traffic conflict in construction operation area

The closure characteristics of one-way lane closure construction area make drivers have to change lanes to realize driving purpose when passing the section of construction area, so there are a lot of forced lane change behaviors in one-way lane closure construction area. Based on the investigation of the proceeds of the lane changing data and traffic data, number of Yang Junyi conflict for security index, using VISSIM to lane trajectory model, and use the SSAM analysis method to analyze conflict, adjust the TTC and PET value, will get the conflict number compared with the observed number of conflict, conflict analysis shows that the frequent lane changing and the frequent lane changing circumstances, conflict differ greatly, prove that frequent lane changing significantly influence on traffic safety of whole[4].

Wu et al. have made a lot of analysis and research on the safety problems in expressway construction areas. Due to closed lanes for construction, the number of lanes available for vehicles to pass through the expressway construction areas has been reduced, and vehicles are mainly in confluent, galloping, diverging and other driving states when passing through the construction areas. In the absence of data statistics, they also used traffic conflict instead of traffic accident traffic safety analysis method to analyze the merge behavior characteristics of vehicles in highway construction areas, proposed the measurement index and characterization parameters of merge conflict risk in construction areas, and determined the quantitative standard of merge conflict risk threshold[6].

Li investigated three sections of the highway construction area in lian-huo highway of shanxi, according to the three sections of the highway construction area special road traffic environment and significant traffic conflict phenomenon, using the method of mathematical statistics and traffic conflict theory to construction area traffic flow characteristics, construction area of macro risk analysis and risk of traffic conflict, to research and determine the construction area statistics law of the headway, and put forward the applicable to the construction area, distribution model for the migration of the headway Weibull ; According to the speed of each section of the construction area to carry out macro risk analysis; Based on the standard division of traffic collision time TTC, the collision between the construction area and the rear-end collision is analyzed[8].

Ding used SSAM model to compare and analyze the vehicle running track files under different simulation schemes of the intersection, so as to obtain the impact of setting variable guide lane on the intersection safety, and carries out safety evaluation and analysis through different index parameters of SSAM[9].

From the perspective of simulation conflict, Zhou, Li et al. used indirect safety evaluation model to compare and analyze the simulation conflict before and after the improvement of a road intersection in a city, and obtained the relevant safety evaluation results[11].

From the analysis of highway traffic flow characteristics of construction area, Zhen got the reconstruction and studies reconstruction and the characteristics of traffic accidents, construction area of different section to find out all kinds of factors affecting the safety of the highway construction area traffic, through the analysis of the characteristics of different traffic safety evaluation system, using the method of multi-level fuzzy comprehensive evaluation for some construction section with sui-yue highway safety evaluation[12].

In order to discuss the driving risk and measurement research of expressway construction area, Huang used VISSIM simulation to study the driving risk status of expressway construction area, analyzed the sensitivity of traffic volume parameters, and established the risk evaluation model of each area of expressway construction area by using multiple linear regression and other methods[13].

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Lv et al. combined traffic simulation and traffic conflict technology to establish the traffic safety evaluation process, evaluation index and quantitative evaluation method for the rural highway maintenance section, and carried out safety evaluation for the rural highway maintenance section[15].

Deepti Muleya and Mohammad Ghanimb et al. observed and recorded the actual conflict at an intersection in Doha, Qatar. They used VISSIM micro-traffic simulation software to conduct simulation modeling to generate vehicle and pedestrian tracks, and then used SSAM to analyze the simulated track to identify and study the potential traffic conflict at the intersection.The results show that SSAM can accurately measure conflict between vehicles and people[16].

Researchers from the vehicle characteristics, traffic flow characteristics, traffic flow parameters, such as different angles using different methods such as mathematical statistics, microscopic simulation analysis of the safety of the highway construction area, in the case of certain construction area safety assessment, and put forward the safety assessment for construction area of all kinds of models. Based on the investigation data of a specific construction area, this paper analysis the traffic characteristics of the highway construction area, using the microscopic simulation technology to simulate the construction area of vehicle running status, and combined with alternative accident SSAM for vehicle trajectory of microscopic traffic simulation output file is analyzed, finally USES the SSAM methods to analyze the indicators of the unidirectional lane closed construction area for safety assessment.

3. Safety evaluation system based on traffic conflict analysis

Simulation of traffic conflict technique application in traffic safety evaluation with SSAM microscopic simulation model is established for the research object, using the SSAM trajectory of microscopic simulation model output file conflict analysis to get SSAM index data, and use the data from instead of the actual observed data traffic conflict, the object of study on traffic safety evaluation.

3.1 Definition of traffic conflict and technical application

Traffic conflict is a traffic phenomenon in which a road user and another road user or road facilities approach each other in space and time during driving. If the road user does not take corresponding traffic behaviors, such as changing the speed of the car, adjusting the direction of the car, and stopping suddenly, a collision will occur[2].

Traffic conflict technology is a kind of technology which can quantitatively measure and discriminate the occurrence process and severity of traffic conflict according to certain measurement method and discriminant standard[2].

In 2008, the United States Federal Highway Administration released SSAM, a simulation conflict analysis technology, which can analyze the vehicle trajectory files output by four micro-traffic simulation models, including VISSIM, PARAMICS, TEXAS and AIMSUN, and output the number, location and severity of different simulation conflicts[3].SSAM mainly obtains simulation data through conflict analysis of micro-traffic simulation model, so as to evaluate the safety of specific traffic facilities instead of historical accident data and actual conflict data[2].

3.2 Introduction of SSAM model

Accident Alternative Technology Model SSAM (Surrogate Safety Assessment Model), also known as indirect Safety Assessment Model, is a Model developed by the Federal Highway Administration (FHWA) in 2008 to perform conflict analysis on micro-traffic simulation models.

3.3 Conflict evaluation index

SSAM analysis to identify the effect of conflict between vehicles and categories, common conflict analysis indicators have collision time (TTC, time - to - collision), a time (PET, post - encroachment - time), the Initial speed reduction (DR, Initial deceleration rate), Maximum speed (MaxS, Maximum speed), the Maximum differential speed (DeltaS, Maximum speed differential), etc[3].

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Collision time (TTC) expresses the minimum collision time value observed during the collision.This estimate is based on the real-time position, speed and trajectory of the two vehicles in conflict at a given moment[3].

Encounter time (PET) expresses the minimum post-collision time observed during the conflict.Encounter time is the last time the first car occupies a certain position and the second car subsequently reaches the same position[3]. A value of 0 indicates an actual conflict.

Maximum speed (MaxS) is the maximum speed of two vehicles during a conflict[3].

Maximum speed difference (DeltaS) refers to the relative speed between the two vehicles in conflict[3].

Initial deceleration (DR) refers to the initial deceleration rate of the second car. In fact, this value is recorded as the instantaneous acceleration[3]. If the vehicle brakes, this is the first deceleration value observed in the collision; If the vehicle does not brake, this is a collision with the observed minimum acceleration value.

The above five parameters are the main indicators of SSAM analysis in this paper, among which the TTC, PET and DR parameters are mainly related to the possibility of traffic accidents. If the TTC value is smaller, the PET value is smaller, and the DR value is larger, the possibility of traffic accidents will be greater[9]. MaxS while the other two parameters and the DeltaS are associated with the severity of the possibility of traffic accidents, the greater the value of MaxS, shows that in the process of traffic accident, the greater the speed of the car, then the greater the possibility of the severity of the traffic accident, and when MaxS value is very big, if the value of DeltaS are relatively small, then the two cars are in a state of high speed, in case of traffic accident, the consequences will be serious traffic accidents.

3.4 Definition and type division of simulation conflict

Simulation conflict refers to the fact that in the simulation model, two cars are running on the track of each other in conflict, and there is no traffic accident because one car or both cars take safety measures.

The SSAM model is mainly divided into collision types according to the location information of conflicting vehicles, which mainly include rear-end collision, lane change collision and cross collision.A collision on the same section of road is defined as a rear-end collision if the conflicting vehicles are driving on the same lane all the time. A collision event is defined as a lane change collision if the conflicting vehicle changes lanes during the collision. The conflicts on different sections need to be classified according to the conflict Angle. When the conflict Angle is between 0 and 30 degrees, it is defined as rear-end collision.When the conflict Angle is greater than 85 degrees, the conflict type is defined as cross conflict.Others are defined as lane changing conflicts[3].

4. Case Application Study

4.1 Data and data analysis

4.1.1 Data acquisition

The data used in this paper are the data from the section survey conducted in the construction area of Jiangsu Gaoyou Section of the Beijing-Shanghai Expressway from March to June, 2019.In order to study the change of traffic characteristics of vehicles entering the construction area, the location of traffic data collection points is segmented into lanes from the upstream of the warning area of the construction area to the working area. Use AxleLightRLU11 portable roadside laser traffic survey instrument to investigate time, speed, headway, wheelbase and vehicle type in warning area and upstream transition area;

At the junction between the upstream transition zone and the buffer zone downstream, the equipment SR/D tracking radar traffic survey instrument was used to investigate the speed, time headway and vehicle composition; At the junction of the buffer zone and the work area, the vehicle speed, time headway and vehicle composition are investigated using the equipment SR/D tracking radar traffic

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detector; Working area, using handheld radar speed detector, observers record speed, vehicle type, etc.

4.1.2 Traffic volume statistics and traffic composition

Table 4.1 Statistics of traffic volume in expressway construction area

Road name	Survey point name	Sample size	Traffic volume and traffic composition statistics				
Construction area of Beijing-Shanghai Expressway	Roadside 1	1799	Traffic volume (VEH /h)	605	667	527	-
			Cart rate (%)	20.33	22.49	22.96	-
	Roadside 2	2225	Traffic volume (VEH /h)	658	702	545	320
			Cart rate (%)	21.28	20.66	25.69	23.75
	The SR/D1	1533	Traffic volume (VEH /h)	1533		-	-
			Cart rate (%)	-		-	-
	The SR/D2	1485	Traffic volume (VEH /h)	-	-	1485	
			Cart rate (%)	-	-	-	
	Hand radar 1	677	Traffic volume (VEH /h)	187	490	-	-
			Cart rate (%)	9.63	7.55	-	-
	Hand radar 2	484	Traffic volume (VEH /h)	-	-	484	-
			Cart rate (%)	-	-	6.82	-

4.2 Traffic simulation and parameter calibration

The traffic simulation software adopted in this paper is VISSIM developed by PTV, a German company. The main function of this software is to describe the operation process of traffic flow. VISSIM contains a large number of driving behavior rules and vehicle models, which has a great degree of freedom in simulating the real traffic operation.Moreover, VISSIM simulation modeling does not set the scene, but imports the base map according to the actual survey, so the road network model established conforms to the actual situation.In this paper, VISSIM simulation software is mainly used to establish the simulation model of expressway construction area. The main construction area is the confluent area, with the purpose to obtain the traffic conflict data of the confluent area in the construction area, and then carry out risk analysis based on the traffic simulation conflict data.The simulation modeling in the face of conflict simulation has higher requirements on whether the model can accurately reflect the driving behavior of the actual vehicle. Therefore, strict parameter calibration must be carried out on the simulation model before the safety evaluation using the conflict simulation.

4.2.1 Establish the simulation model

(1) Simulation section establishment

This paper studies the layout form of one-way lane closure in expressway construction area, and the surveyed section is two-way four-lane, and the closed form is the outer lane closure. The specific layout of each control area in the Construction area of The Beijing-Shanghai expressway is shown in FIG4.1.According to the investigation, the distance between AB, BC and CD is 200m.

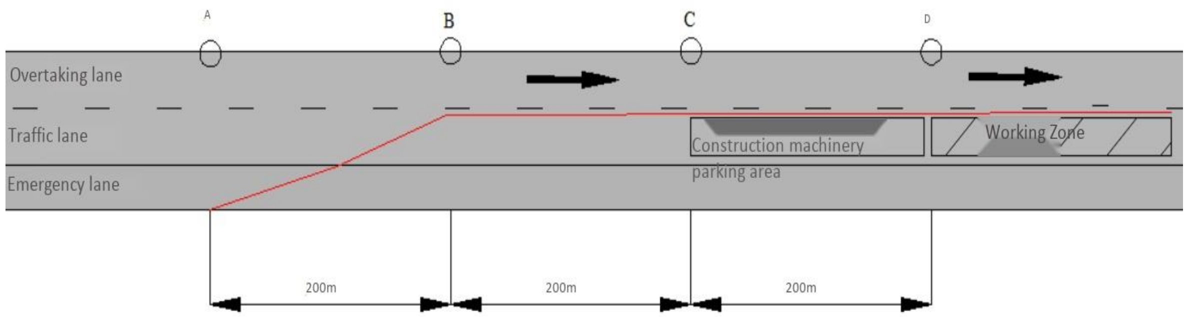

Fig 4.1 Simulation section in Construction area of Beijing-Shanghai Expressway

ISSN: 2414-1895
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(2) Traffic parameter setting

The setting of traffic parameters includes traffic volume, expected vehicle speed distribution and so on. In this simulation experiment, traffic parameters are set according to the data obtained from the survey in the construction area. Among them, traffic volume is selected from the peak hour traffic volume obtained from the survey. The expected speed distribution of each vehicle is obtained from statistical analysis of the survey data.

(3) Setting of driving rules and driving behavior

VISSIM has two models for car following, Wiedemann74 for inner city roads and Wiedemann99 for highways[21]. In this paper, the highway section is studied, so the car following model is selected as Wiedemann99 physiological and psychological model.

4.2.2 Calibration of traffic simulation parameters

(1) Parameter calibration of following vehicle model

The research object of this paper is the section of expressway construction area, so Wiedemann99 physiological and psychological model suitable for expressway is selected. The following is the calibration of some parameters of this model according to the conditions of the construction area studied.

In VISSIM software, 10 vehicle tracking model parameters can be adjusted according to Wiedemann99 physiological and psychological model, as shown in Table 2[20,21]. 1 foot (ft) =0.3048 m (m).

Table 4.2 Introduction of tracking model parameters table

The parameter name	Meaning and Function	The default parameters
CC0, stop spacing	The average expected distance between two stop vehicles	4.92 ft, 1.5 m
CC1, headway	The time headway the driver expects to maintain for a given speed	0.9 s
CC2, the following car variable	Longitudinal swing constraints for front and rear vehicles	13.12 ft, 4 m
CC3, threshold for entering the following car state	The time when the driver of the rear vehicle begins to slow down after entering the following state	- 8 - s
CC4 and CC5, thresholds of 'following car' state	Control the speed difference between the front and rear vehicles in the 'following vehicle' state. When the velocity difference is negative, CC4 is used;When the velocity difference is positive, use CC5	CC4 is 0.35 ft/s; CC5 0.35 ft/s
CC6, speed vibration	The influence of distance on the vibration of vehicle speed during following the vehicle.	11.44
CC7, vibration acceleration	The actual acceleration during the swing	0.82 ft/s^2And 0.25 m/s^2
CC8, acceleration of stopping	The expected acceleration at start at rest	11.48 ft/s^2And 3.5 m/s^2
CC9, acceleration at 80km/h	The expected acceleration at 80km/h	4.92 ft/s^2And 1.5 m/s^2

For the above 10 parameters of the car following model, CC1 and CC2 need to be calculated and obtained according to the specific construction area of the survey, and other parameters in this paper

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take the default value of VISSIM software.Where, the calculation formula of CC1 is shown in Formula (4-1)[22].

$$CC1 = -0.0023 \times avg.QDR + 5.3146(s) \tag{4-1}$$

Where, AVg. QDR is the average queue traffic (traffic per lane per hour/PCPHPL), and its calculation formula is shown in Formula (4-2)[22].

$$avg.QDR = 2093 - 154 \times f_{LCSI} - 194 \times f_{barrier} - 179 \times f_{area} + 9 \times f_{lateral-12} - 59 \times f_{day-night} \tag{4-2}$$

Where, f_{LCSI} =1/ (open lane ratio ×number of open lanes)

Open lane ratio = the ratio of the number of open lanes to the total number of lanes

$f_{barrier}$ =0, concrete isolation;1. Soft isolation (taper drum or polyethylene drum)

f_{area} =0, city;1, rural

$f_{lateral-12}$ = Transverse clearance -12 (ft) (min =-11.9 ft, Max =0 ft)

$f_{day-night}$ =0, daytime;1 night, night

According to the actual situation of the construction area investigated in this paper, The values of f_{LCSI}, $f_{barrier}$, f_{area}, $f_{day-night}$ are 2,1,1 and 0.

This paper discusses the closed condition of one-way outside lane. Therefore, after calculating the value of CC1, the value of CC2 should be obtained according to the QDR correction table of CC1 and CC2 in the configuration of half lane.The calibration table is shown in Table 4.3.

Table 4.3 QDR correction table of CC1 and CC2 in 1/2 lane configuration[20]

CC2 value (ft)	PCPHPL value calculated by CC1 (s)								
	0.90	1.08	1.26	1.44	1.62	1.80	2.70	4.50	6.30
13.12	2373	2114	1978	1740	1662	1570	1181	794	622
15.74	2367	2204	1797	1733	1660	1553	1176	792	621
18.37	2298	2137	1767	1729	1632	1530	1169	791	619
20.99	2214	2070	1738	1693	1604	1502	1154	789	617
23.62	2185	2057	1763	1677	1580	1478	1143	787	617
26.24	2045	1952	1702	1642	1555	1452	1127	786	613
39.36	2062	1905	1751	1603	1507	1406	1059	768	606
65.60	1783	1660	1556	1443	1338	1253	961	701	551
91.84	1530	1456	1362	1277	1199	1126	882	663	537

Where, 13.12ft and 0.9s are the default values of CC2 and CC1 in VISSIM respectively.

Based on the above table and formula, the final CC2 and CC1 values are 23.62 feet (7.2m) and 2.07s respectively.

(2) Calibration of lane change model parameters

There are two lane change models in VISSIM: free lane change and necessary lane change. According to the status of the construction area surveyed in this survey, the lane change model was selected as the necessary lane change based on the path. The parameter Settings of the lane change model are shown in Table 4.4.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202010_6(10).0040

Table 4.4 Parameters setting of necessary lane change model

The parameter name	The parameter value
Maximum deceleration is m/s^2)	3.00
1 m/s^2/ distance (m)	200
Acceptable deceleration (m/s)^2)	0.50
Wait time before vanishing (s)	60.00
Minimum headspace (m)	0.50
Safety distance reduction factor	0.60
Coordinate the maximum deceleration of the brake (m/s)^2)	3.00

(3) VISSIM vehicle model parameter calibration

In the 2 d / 3 d model of distribution function, the parameters of the model for vehicle calibration of the selected models, cars, trucks, buses, is to use the default model of VISSIM, and car models is the sum of different kinds of car distribution, the rest of the two types of models is to import 3 d model, vehicle model parameters as shown in table 4.5.

Table 4.5 Vehicle model parameter Settings

Vehicle type	Vehicle length (m)	Vehicle width (m)	The CHOSEN 3D model
The car	4.11-4.76	1.50	Car1-6
van	10.21	2.50	Truck
buses	11.54	2.50	Bus
Station wagon	4.72	1.80	Land Cruiser
Large trailer	12.25	2.50	TruckUS2 and TrailerUS2

4.2.3 Output vehicle running track file

After the simulation parameter setting is completed, after selecting the file in the evaluation column of VISSIM software menu bar and selecting the output column in the file, the vehicle running track file for SSAM analysis can be obtained after the simulation operation.

4.3 Coupling of traffic simulation and conflict evaluation

SSAM, a collision analysis software developed based on accident substitution technology, reads and analyzes the vehicle track file output by micro-traffic simulation software VISSIM after simulation operation, so as to observe the values of various parameters of SSAM and then evaluate the traffic conflict situation in the construction area.

5. Traffic conflict evaluation of construction area based on SSAM

As shown in Table 5.1, SSAM software was used to analyze various indexes of the simulated vehicle trajectory file.

Table 5.1 Numerical statistics of SSAM analysis indicators

SSAM parameters	The minimum value	The maximum	The average	The variance
TTC	0.00	1.50	0.38	0.39
PET	0.00	1.00	0.20	0.11
MaxS	5.28	26.11	10.99	42.12
DeltaS	0.39	6.11	2.62	2.95
Dr.	7.32	0.48	1.86	9.01
MaxD	7.32	0.48	2.04	8.82
MaxDeltV	0.20	4.98	1.77	2.15

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Table 5.2 SSAM analysis of conflict types and quantity statistics

Conflict types	The number of statistical
Tracing cauda conflict	16

The Map visual display of SSAM for conflict events is shown in Figure 5.1.

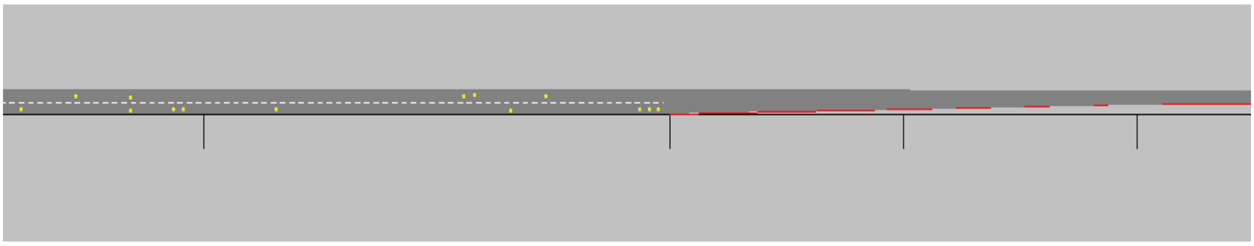

FIG. 5.1 Traffic conflict points shown by the road network model

From above 5.1 for the analysis of the simulation scheme of vehicle trajectory according to situation of conflict, can be observed, and the traffic conflict occurs mainly in warning area into the upper zone of transition section, because the car warning from the end of the area into the upper transition zone, the traffic present phenomenon of confluence, drivers need according to oneself to deceleration operation condition judgment, the traffic here is relatively complex, so it is construction area prone to the extent of traffic conflict, may even cause serious accidents, from the viewpoint of traffic safety, to set up warning signs, traffic signs in this segment, remind drivers drive carefully,It is necessary to arrange the flag bearer to direct the traffic on the spot according to the situation to ensure the traffic safety.The setting of traffic cone should be reasonable and gentle, and the Angle of vehicle confluence should not be too extreme, and safety facilities such as isolation pier should be arranged when necessary to ensure safety.

6. Conclusion

For the study of traffic simulation and SSAM method applied in the field of traffic safety evaluation, analysis of the highway construction area traffic safety situation, based on the one-way highway lanes closed construction area as an example, based on the survey data of construction area, using the VISSIM simulation software to the simulation modeling of construction area road, in the process of modeling, according to the survey of the construction area of the specific conditions, the simulation model of vehicle with the simulation models and lane changing model parameters calibration. According to the vehicle running track file obtained from simulation modeling, SSAM analysis method is used to analyze the traffic conflict of vehicle running track combined with SSAM specific indicators (TTC, PET, etc.), and various index parameters of SSAM are analyzed, so as to evaluate the safety status of construction area. This paper analyzes the traffic conflict and traffic safety in construction area.

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