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VISSIM Simulation Parameter Correction of Expressway Capacity under Traffic Accident

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***Abstract*—Traffic accident on expressway is one of main reasons of traffic congestion on the road section and the road network. In order to accurately estimate expressway capacity under traffic accident and upstream direct traffic diversion, a parking model of traffic accident section is presented with VISSIM parking tool, and sensitivity of simulation parameters is analyzed with single-factor displacement method. Then choosing travel time as the correction index of the simulation model parameters, a VISSIM simulation parameter correction program based on genetic algorithm is designed. Finally, a rear-end accident on four-lane expressway is used as case study, the results show that the relative error rate between simulation and actual investigation is 3.04%, which validates that the correction model of simulation parameter is reasonable.**

Keywords-traffic accident; traffic capacity; VISSIM; parameter correction; genetic algorithm

I. INTRODUCTION

According to the U.S. Federal Highway Administration FHWA statistics, 70% of expressway traffic congestion caused by traffic accidents [1], and the expressway traffic accident can easily cause traffic congestion of expressway section and road network. Accurate forecast on traffic capacity under accident condition by effective technique can not only quantitatively guide traffic diversion, but also can make full use of the road network traffic capacity. At present, the capacity estimation methods under emergency conditions can be divided into three types: parameter estimation, nonparametric estimation and simulation estimation. The most widely used method of parameter estimation is the algorithm in Highway Capacity Manual (USA)[2], but it will inevitably lead to errors due to the calculator subjective judgment and is affected by the regional environment. Adeli[3] presents a nonparametric estimation method based on a neural network of quantized interaction variables using fuzzy inference, but it is too complicated to be applied. Weng[4]-[5] built a decision tree model, because continuous variables are discretized to a certain level, it will affect the accuracy of the model. The simulation estimation method can well estimate traffic capacity when the field data and information are lacking, but the simulation result accuracy is greatly affected by the parameter values obviously. So in order to obtain the real simulation and accurate output results, it is necessary to modify the simulation model parameters according to the real traffic condition. Heaslip[6] uses the simulation method to estimate the capacity of main road construction area. Because the calibration algorithm costs much calculation time and operation space, it is necessary to apply the simulation method to correct the parameters of the micro simulation model.

In the paper, the parking lot tool in VISSIM is used to imitate accident conditions and build a road accident "parking lot" model, and the calibration parameters based on parking lot model are present. Secondly the single factor substitution method is used to test sensitivity of parameter, and a real coded genetic algorithm is used to design the VISSIM simulation parameter correction program on the MATLAB platform. Finally, a case is given to verify the validity of the model and the rationality of the calibration results.

II. SENSITIVITY ANALYSIS OF CALIBRATION PARAMETERS BASED ON PARKING LOT MODEL

A. *Calibration Index and Optional Parameter Set*

The calibration index is the measurement data that compares the results of the field data and the simulation evaluation data, which can reflect the traffic flow state of the field and simulation. The travel time is chosen to correct the simulation parameters of accident expressway section. The parameters that affect the accuracy of the simulation model in VISSIM are car-following module and lane-changing module. Tab.1 lists the simulation parameters involved in the simulation of vehicle driving behavior.

TABLE I. PARAMETERS SET OF VISSIM CALIBRATION TO SIMULATE DRIVING BEHAVIOR UNDER THE ACCIDENT CONDITION

Car-following module	Minimum forward sight distance/ m
	Maximum forward sight distance / m
	Parking distance(CC0)/m
	Headway (CC1)/ s
	Car-following variable (CC2)/ m
	The threshold of car-following status (CC3)/ s
	Vibration acceleration(CC4)/ m/s2
Lane-changing module	Minimum headway/m
	Safety distance reduction factor
	Overtaking deceleration rate

B. *Parking Lot Model*

There isn't accident model in VISSIM, but the accident condition can be simulated by setting signal light, closing motor way and using parking lot tools. In the parking lot model, two parking lot tools are used to describe accident vehicle and warning signs, and parking time is regarded as accident time. Assuming that first parking lot refers to the warning signs and second parking lot represents accident location. Some vehicles will park in the two parking lots in order to show the motor lane is occupied. The distance from first parking lot to second parking lot is the accident road section length. Accident condition parameters are shown in Tab.2.

TABLE II. PARAMETER CHARACTERIZING OF ACCIDENT CONDITION

Parameters	value
First parking lot location /m	400
Length of first parking lot /m	5
Second parking lot location /m	450
Length of second parking lot /m	10
Accident time /min	5
Accident duration/min	30

C. *Sensitivity Analysis of Calibration Parameter Set*

Sensitivity analysis of calibration parameter set not only can filter out the core correction parameter set which has significant impact on the model index, but also can determine the reasonable value range of each parameter. In the paper, the Lane 1 rear-end collision case at the urban 3 lane straight road is selected to analyze the sensitivity analysis and establish VISSIM simulation model. The model data are shown in Tab.3.

TABLE III. BASIS DATA OF SIMULATION MODEL

Parameters	value
Road length /m	500
One-way lane number	3
Single lane width /m	3.5
Expected velocity /(km/h)	80
Traffic volume /(veh/h)	3000
Truck proportion	8%

The of single factor replacement method is used to analyze each parameter in Tab.1, and the calibration parameter sets are determined. The parameters and its range are shown in Tab.4.

TABLE IV. SENSITIVE PARAMETER SETS TO TRAVEL TIME IN VISSIM

Module	Parameter	Value range
Car-following module	Parking distance(CC0)/m	[0.5,5]
	Headway (CC1)/ s	[0.5,5]
	Car-following variable (CC2)/ m	[0.5,5]
	The threshold of car-following status (CC3)/ s	[-12,-3]
Lane-changing module	Minimum space headway (DD)/m	[0,10]

III. Correction Procedure Based on Real Coded Genetic Algorithm

According to the sensitivity analysis results, the correction index is travel time, the parameters to be corrected are parking distance (CC0), headway (CC1), car-following variable (CC2), the threshold of car-following status (CC3) and minimum space headway (DD). The function relation between the parameters to be corrected and the calibration index in VISSIM is shown in Eq. (1).

$$\{CC0, CC1, CC2, CC3, DD\} = f^{-1}(\{T\}) \quad (1)$$

Different from most researches, the genetic algorithm designed in the paper mainly uses the real coding method, which avoids the occupied computer time problem by binary coding and decoding and the contradiction between calculation precision and quantity. The correction algorithm rules are made as follows:

(1) **Color coding:** using Eq. (2) the linear transformation to optimize the variables to [0, 1] interval.

$$x(i,j) = x\min(i) + y(i,j)(x\max(i) - x\min(i)) \quad (2)$$

In which: $x(i,j)$ ——Variables to be optimized;

$y(i,j)$ ——Genes, normalized parameter values, $0 \le y(i,j) \le 1$;

$x\min(i)$——Low limit of parameter $x(i)$;

$x\max(i)$——Upper limit of parameter $x(i)$;

p——Parameter to be identified;

N_{pop}——Group size;

i ——Node value, $i = 1, 2, p;$;

j——Individual No. in a group, $j = 1, 2, \cdots, N_{pop}$.

Normalized parameter values are combined to form a chromosome whose coding length is *p*. According to the sensitivity analysis results, there are 5 variables to be optimized, so *p*=5. Variables and their ranges refer to Tab.4.

(2) **Population initialization:** we can get component the uniform random numbers of set N_{pop} on the [0, 1] interval ($\{u(i,j)\}(i = 1, 2, p; j = 1, 2, \cdots, N_{pop})$).

$u(i,j)$ is used as the parent value $y(i,j)$ of the initial population, the optimal variable value $x(i,j)$ can be calculated by $y(i,j)$.

(3) **Fitness function:** the individual variables are saved into VISSIM network file (*.inp). The average travel time of all vehicles in the accident period is output by operating the file *.inp. The absolute difference value between the output

average travel time and the actual average travel time is regarded as the objective function value $f(j)$, shown in Eq.(3).

$$f(j)=\left|t^{F}-t^{0}\right| \tag{3}$$

In which: t^{F} ——the output average travel time;

t^{0} ——the actual average travel time.

According to the objective function, the fitness function is shown in Eq.(4), and the judging condition of the optimal solution is the maximum fitness.

$$F(j)=\frac{1}{f(j)+1} \tag{4}$$

(4) **Selection:** outputting first generation sub-individual $\{y_1(i,j)\}(i=1,2,p;j=1,2,\cdots,N_{pop})$. Using proportional selection, $\{F(j)\}$ and it's corresponding $\{y(i,j)\}$ are sorted from large to small. the election probability $p_s(j)$ of the parent individual $y(i,j)$ is

$$p_s(j)=\frac{F(j)}{\sum_{j=1}^{N_{pop}}F(j)} \tag{5}$$

$$p(j)=\sum_{k=1}^{j}p_s(k) \tag{6}$$

Sequence $\{p(j)\,|\,j=1,2,\cdots,N_{pop}\}$ divides the interval [0,1] into N_{pop} sub-intervals, one-to-one correspondence relation is established between the sub-intervals and $\{y(i,j)\}$, N_{pop} -1 individuals are selected based the roulette selection method.

(5) **Crossing:** a pair of parents $\{y(i,j_1)\}$ and $\{y(i,j_2)\}$ is randomly selected, and the random linear combination, shown in Eq.(7), is used to generate the individual $y_2(i,j)$ of sub-individual $\{y_1(i,j)\}$:

$$y_2(i,j)=\begin{cases}u_1y(i,y_1)+(1-u_1)y(i,y_2),u_3<0.5\\ u_2y(i,j_1)+(1-u_2)y(i,j_2),u_3\geq 0.5\end{cases} \tag{7}$$

u_1,u_2,u_3 are random numbers of interval [0,1]. Based on crossing operation, N_{pop} sub-individuals are generated.

(6) **Mutation:** N_{pop} random numbers whose probability are $p_m(j)=1-p_s(j)$ are used to replace the individual $y(i,j)$, then the sub-individual $y_3(i,j)$ is shown in Eq.(8)..

$$y_3(i,j)=\{\begin{array}{l}u(i),u_m<p_m(j)\\ y(i,j),u_m\geq p_m(j)\end{array} \tag{8}$$

In which, $u(i)(i=1,2,\cdots,p)$ and u_m are random number on the interval [0,1].

(7) **Iteration:** $\{y_3(i,j)\}(i=1,2,p;j=1,2,\cdots,N_{pop})$ is regarded as a new parent population, going to Step (3) for next evolution process.

Based on the invoked Function GA in MATLAB and the modified main function, using MATLAB to modify the File *.inp and achieving interaction with VISSIM by file configuration and loading.

IV. CASE ANALYSIS

An accident case (Fig.1), rear end collision of 3 cars, at Lane 4 of 4-lanes urban expressway, is used to verify and analyze the parameter calibration results. The accident is far away from the upstream inlet and outlet, and the warning sign is set at 20m from the rear of the third accident car. There is a short time upstream congestion. Slow speed, obvious car following and lane changing behavior at the accident bottleneck section. The surveyed basic data of the accident section are shown in Tab.5.

FIGURE I. ACCIDENT CASE SITE

TABLE V. ACCIDENT SECTION DATA

Parameters	value
Distance to upstream inlet and outlet /m	800
Distance to downstream inlet and outlet /m	1300
One-way lane number	4
Lane width /m	3.75
Design speed /(km/h)	100

Travel time between detection lines and headway distribution is respectively calculated by Eq. (9) and (10), and the extracted video data are shown in Tab. 6.

$$T_i = (N_{i2} - N_{i1})\frac{1}{F} \tag{9}$$

$$H_{is} = (N_{i2} - N_{(i-1)2})\frac{1}{F} \tag{10}$$

In which, i——Vehicle No.;

T_i ——Travel time of vehicle V_i from A to B, s;

N_{i1} ——Video frame numbers of vehicle V_i arriving A;

N_{i2} ——Video frame numbers of vehicle V_i arriving B;

F ——Video frame numbers per second, $F = 26$ /s;

H_{is} ——Headway passing B during accident, s.

TABLE VI. EXTRACTED VIDEO DATA OF ACCIDENT SECTION

Parameters	value
Length of accident section/m	32
Car hour traffic volume/veh	4320
Truck hour traffic volume/veh	410
Truck proportion	8.7%
Accident duration /min	30

A. *Establishment of Case Simulation Model*

Simulation road length is 650m, single lane width is 3.75m. Warning sign is set at 20m to accident car rear. Simulation model is set as follows: Setting first parking lot, 5m long, at 550m to simulation road origin as the warning sign, and setting second 12m parking lot, 12m long, at 570m to simulation road destination as the accident section length (Fig.2).

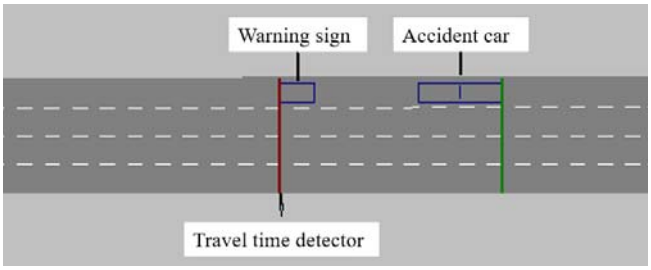

FIGURE II. SIMULATION MODEL DIAGRAM

The simulation operation parameters and the accident evaluation indexes are as follows: The simulation time is 1800s, the rear-end collision occurs at 180s. The initial position of the travel time detector is respectively located origin and destination of the accident road section. The parameters are collected during 300s~1500s, record once every 200s, totally 6 groups data are collected. The parking route decision and the local route decision are valid in the whole simulation, from 180s to 1500s, the average value of parking distribution is 1320s. After the accident vehicle parking, following vehicles will change lane based on the local route decision in order to simulate the land occupied by the accident vehicles. Traffic volume, vehicle composition, composition ratio, expected speed are set according to the basic data.

B. *Results of Simulation Parameter Calibration and Capacity Estimation*

After the case simulation model is built, the simulation parameters are corrected by the correction program described above. Calibration results are shown in Tab.7.

TABLE VII. CORRECTION RESULTS OF THE SIMULATION MODEL PARAMETER

Simulation model parameters	Calibration results
Parking gap /m	1.33
Headway /s	2.42
Car-following variable /m	4.81
Threshold of car-following status	-3.95
Minimum space headway/m	2.89

The detected traffic volume at the road bottleneck in simulation are shown in Tab.8, the maximum 15min traffic volume is used to calculate capacity of the accident road section.

TABLE VIII. TRAFFIC VOLUME OF BOTTLENECK IN SIMULATION

Detection time /s	300	600	900	1200	1500	1800
traffic volume /veh	303	305	304	297	301	304
Detection time /s	2100	2400	2700	3000	3300	3600
traffic volume /veh	423	426	418	424	425	423

Result comparison between the simulation and the actual is shown in Tab.9.

TABLE IX. COMPARISON RESULT OF SIMULATION AND ACTUAL MEASUREMENT

Comparison items	Actual results	Simulation results
Maximum 15min traffic /veh	885	912
Traffic capacity /(pcu/h)	3848	3965
Relative error	3.04%	

Based on Tab. 9, the relative error value is 3.04% which shows that the simulation results are accurate, and the simulation calculation framework and the calibration procedure are reliable.

V. CONCLUSION

1. A parking lot model is established with VISSIM "Parking" tool, and the parameter sensitivity analysis is carried out by using the single factor replacement method. A parameter

set, sensitive to travel time, is established. The parameters include: parking gap, headway, car-following variables, and the minimum space headway.

2. Taking travel time as the correction index of the simulation parameters at the accident road section, based on the real coded genetic algorithm, VISSIM simulation parameter correction program is designed by using the GA function of MATLAB which improve simulation precision and reduce calculation amount.

3. A case study is given, and the relative error between the measured results and the actual results is 3.04%, which proves that the algorithm and the calibration parameter are reasonable.

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