Modeling freeway real-time operating safety evaluation based on fault tolerance

Yang Zhiqing[1], Xiaoli Du[2], Zhongyin Guo[1] & Benmin Liu[1]

[1]School of Transportation Engineering, Tongji University
Room 405, Department of Road and Railway Engineering, Tongji University, 1239 Siping Road
200092 Shanghai, China
Phone: +86-21-65988812
Fax: +86-21-65981430
E-mail: zhiqing_yang@sina.com

[2]School of Electronics and Information Engineering, Tongji University
1239 Siping Road
20009 2Shanghai, China

Abstract

This paper first analyzes the influence of the dynamic changing of weather, road and transportation on freeway operating safety. For the purpose of accidents avoidance, 4 safety grades are defined based on fault tolerance of traffic flow. Fault tolerance represents the risk of rear-end while driving on freeway. Good fault tolerance means even if some accidents happen on one or several vehicles, other vehicles would still stay safe and the entire traffic flow could be ensured to pass safely. Based on the analysis of dynamic data of weather, road and traffic condition collected by freeway monitor system, the dynamic thresholds of speed and density are determined. Finally the real-time safety grade of freeway is obtained by comparing the dynamic thresholds with the real-time speed and density. The simulation results show that the freeway real-time operating safety evaluation model based on fault tolerance proposed in this paper could be used to not only estimate the real-time driving risk of vehicle under different weather, road and traffic condition, but also evaluate the impact of management. The evaluation results match reality pretty well. The model is suitable for the freeway with complete information collection devices and high-level informatization.

Keywords: real-time safety evaluation; fault tolerance; operating safety; safety grade; freeway

1. Introduction

During the recent 20 years, the freeway networks of China have been constructed primarily. It not only accelerates the development of China economy, but also brings convenience on people's daily life. However, like every coin has two sides, the freeway administrators and users are also much troubled by its high accident rate and striking accident damage. It is reported that the accident rate of freeways is only the 30%-50% of that of highways in developed country. While in China, the accident rate of freeways is 4 times of that of highways, and major accidents occur frequently (Zhiyi Sang, 2001). In recent years, with the increasing investment from government, the freeway's facility, service level and management level are all improved a lot, but the safety status is still unsatisfactory. According to the statistic data of Ministry of Public Security of China, 6407 persons, which is 2.8% increase of that in 2004, died in the freeway accidents in 2005 (Ministry of Public Security of China, 2006).

Researches show that the vehicle space-time distribution, weather, alignment and terrain will all affect operating safety of freeway, and the objective and efficient evaluation of them is the basic premise of freeway managing and controlling. So an urgent research needed to be performed is to establish an efficient and objective freeway real-time operating safety evaluation model, which integrates factors like weather, road and traffic condition, in order to find the hidden trouble of freeway operating in time. Furthermore, accident rate and accident severity could be reduced through suitable guiding and controlling.

Based on the data collected by freeway monitor system, this paper considers the influences of weather, road and traffic condition, and establishes a freeway real-time operating safety evaluation model verified by simulation software. This model could be an adviser for freeway management, or be used to evaluate the impact of management. The rest parts of this paper are organized as follows. Section 2 introduces the related work on freeway real-time operating safety evaluation. The influences of weather, road and traffic condition to safety are analyzed in Section 3, and the model is established also. Section 4 verifies the model by simulation software and shows the results. Section 5 summaries this paper.

2. Literature Review

Until now, freeway safety evaluation has attracted interests of researchers all over the world. The evaluation methods could be divided into two categories including intensity analysis and probability and statistics methods. Those methods are mainly used to evaluate the synthetical safety of freeway during a long period, and could be considered as the guidance of accident black-pot discrimination and safety update. However, they are static evaluation method, and are helpless to the dynamic changes of weather and traffic condition, so they can't provide support to freeway real-time operating safety management.

USA, Japan and some countries in Europe have developed ITS (Intelligent Transportation System) for many years, and now they are in the phase of application. For example, the SOCRFTES (System of Cellular Radio For Traffic Efficiency and Safety),which is used in GothenBurg of London and Hessen of south Germen, could provide dynamic road network information and real-time traffic information, locate vehicle flow, give an road status alarm, tell drivers the accidents occurring ahead and weather prediction information etc.(Xiaoqiang Wu, 2000). However SOCRFTES just detects environment, road, traffic and accident information, and then provides those information to drivers. It can not evaluate the real-time risk of accident on road.

The RWIS (Road Weather Information System) in New Jersey, USA could collect weather, road, traffic volume and jam information by sensors, and then release weather information and speed limit to drivers through signals, variable speed limit and broadcast. Simultaneously, speed limit is performed by traffic police (Lijun Zhang, 2006). This system mainly detects all sorts of information for the purpose of accidents avoidance and traffic control. It can not evaluate the real-time safety of road.

By taking the influences of weather and traffic condition into account, two indices are proposed by Xiaoqing Huang (2006) to evaluate the real-time risk of driving, while neglecting the influence of road environment; furthermore, it focuses on the safety of vehicle flow, rather than road segment, and might incur some difficulties on freeway real-time management and control. Though the speed limits proposed by Lijun Zhang (2006), integrates all sorts of weather conditions in order to analyze the driving safety of single vehicle under different weather, it is lack of considering the influences incurred by road and traffic condition.

EAMSS (Emergent Affair Management and Succor System) is an accident remedy system. It examines the emergent accidents that have already happened and provides succor service. To the safety issue of freeway, accident detecting and succoring are necessary, while the

even more important tasks are accident prevention and management. Thus, it is an urgent mission to evaluate freeway real-time operating safety for the purpose of accident prevention and freeway management. Finally, it will be of a great benefit to the driving risk decrease and accident reducing.

3. Analyze and Modeling

According to statistic, rear-end is the dominative accident type on freeway. When a leader vehicle brakes or stops abruptly due to vehicle malfunction or the change of traffic condition and weather, sometimes there is no time for the following vehicle to take measures. That usually results in rear end, rolling over, or even worse a chain of collision. In addition, some freeway facilities cannot satisfy the requirements of road safety. For example, the inadequate parking bays and the too long distance between service areas, so drivers usually park illegally when their cars get broken. Furthermore, drivers don't turn on hazard warning lamps or are unable to place a warning board behind their vehicles, which would cause much more rear-end accidents (Zhongmin An, 1999; Wenwu Wang and Qiansheng Li, 2001). Rear-end accidents are affected by dynamic factors like weather, road and traffic condition remarkably, and can hardly be analyzed through static safety evaluation methods. Therefore, this paper chiefly dedicates to the research work of evaluating the risk of rear-end on freeway by dynamic methods.

3.1 Impact Factors Analysis

It is well-known that traffic accidents result from many factors like signs, marking, traffic equipment, alignment and lighting etc. In order to evaluate the real-time operating safety of freeway, the relationship among safety and those factors should be found firstly. This paper considers weather, alignment and traffic condition the dominating factors that affect freeway operating safety.

Weather

Weather is a significant factor that influences driving safety. Fog makes it difficult for drivers to discern road and traffic ahead by reducing visibility. Rain could reduce the friction coefficient of surface, which will stretch the brake stopping distance of vehicle. Heavy snow not only results in low visibility, but also brings low coefficient of friction on road surface by cooling and icing. In a word, the above three weathers mainly affect driving safety through reducing visibility and friction coefficient of surface.

Alignment

The curve and terrain undulation of alignment usually restrict the sight of drivers. From the eyesight examination results, it is easy to know that the discriminability of eyes have a peak value, so people always observe objects with his clearest eyeshot. During driving, the object that drivers care about most is the road situation ahead, so he will always focus on road rather than anything else. The longest road distance that could be seen clearly by drivers is defined as SCSD (Spatial Sight-Distance) by Zhiqing Yang (2005). On each location of freeway, there exists a SCSD (Spatial Sight-Distance). The influence of alignment on driving safety is reflected by SCSD.

Traffic condition

The traffic condition of freeway could be divided into free flow and non-free flow. To a single vehicle, the difference of two traffic conditions is whether there exists a vehicle running ahead in the driver's sight. In free flow, driver needs to discern whether something will appear suddenly on the road surface ahead, and takes certain measures to avoid crash. While in non-free flow, driver would care about whether leader vehicle will brake abruptly, and accordingly take measures to avoid rear-end.

Based on the impact factors analysis shown above, it is easy to found that weather, road and traffic condition all play an important role in the driving safety. The weather and traffic condition sometimes would change unexpectedly. Therefore, in order to ensure the vehicles' driving safety, traffic flow should provide fault tolerance. Fault tolerance means vehicle could safely brake to stop in normal traffic condition when leader vehicle brakes suddenly or something appear abruptly on the surface ahead. Good fault tolerance implies the low potential hazard of driving. It means even if the leader vehicle brakes suddenly or something appears abruptly, other vehicles still could be driven safely. Bad fault tolerance does not mean accidents must happen, while it implies the high potential hazard of driving. In the author's opinion, fault tolerance could be denoted by the relative position between leader vehicle and following vehicle, or vehicle and barrier, when they brake to stop. Thus based on the relative poison, safe grades are defined as 1, 2, 3 and 4, which mean safer, safe, dangerous and more dangerous. The higher the safety grade is, the better the fault tolerance is, and the lower probability the accidents will happen, and vice versa.

3.2 Single Vehicle Driving Safety Analysis

According to the impact analysis on traffic condition mentioned above, there are different requirements on fault tolerances in free flow and non-free flow. Therefore, this part will focus on the single vehicle operating safety in these two traffic conditions.

Non-Free Flow

When vehicle B is in non-free flow, the space headway between vehicle B and leader vehicle A at moment t_0 could be supposed as S (m), and the vehicle lengths of both as h (m). If vehicle A brakes now, vehicle B will also brake after taking reaction time t (s). Due to the stop sight-distance (SSD) equation of ASSHTO, their SSD are:

$$S_A = \frac{V_A^2}{254(f \pm g)}$$

(1)

$$S_B = 0.278V_B t + \frac{V_B^2}{254(f \pm g)}$$

(2)

where: S_A——stop sight distance of vehicle A (m);

S_B——stop sight distance of vehicle B (m);

V_A——speed of vehicle A (km/h);

V_B——speed of vehicle B (km/h);

t——reaction time of driver (s);

f——surface friction coefficient;

g——gradient expressed as a decimal fraction.

Free Flow

When vehicle C is in free flow, the longest distance that driver can see at moment t_0 could be supposed as l (m), and the vehicle lengths as h (m). If a barrier appears now, vehicle

C will brake after taking reaction time t (s). Due to the stop sight-distance (SSD) equation of ASSHTO, the SSD of vehicle C is:

$$S_C = 0.278V_C t + \frac{V_C{}^2}{254(f \pm g)}$$

(3)

where: S_C——stop sight distance of vehicle C (m);

$\quad\quad\quad V_C$——speed of vehicle C (km/h).

If $S_A + S - S_B > 2h$ or $l - S_C > h$,that is to say the distance between the head of vehicle B and the rear of vehicle A, or the head of vehicle C and barrier, is longer than the vehicle length when stopping. It indicates that the fault tolerance of vehicle A and B, or vehicle C, at moment t_0 is very well, and the safe grad is 1, which means safer.

If $h < S_A + S - S_B \leq 2h$ or $0 < l - S_C \leq h$, that means the distance between the head of vehicle B and the rear of vehicle A, or the head of vehicle C and barrier, is shorter than vehicle length, but longer than zero while stopping. Crash does not occur at this situation, while the safe distance is a little shorter. It indicate that the fault tolerance of vehicle A and B, or vehicle C, at moment t_0 is still accepted, and the safe grad is 2, which means safe.

If $0 < S_A + S - S_B \leq h$ or $-h < l - S_C \leq 0$, namely vehicle B have superposed vehicle A, or vehicle C have outstripped barrier when stopping. Slight crash has occurred at this moment. It indicates that the fault tolerance of vehicle A and B, or vehicle C, at moment t_0 is bad, and the safe grad is 3, which means dangerous.

If $S_A + S - S_B \leq 0$ or $-h < l - S_C \leq 0$, that indicates vehicle B have passed through vehicle A, or vehicle C have passed through barrier when stopping. Heavy crash has occurred at this moment. The fault tolerance of vehicle A and B, or vehicle C, at moment t_0 is very bad, and the safe grad is 4, which means more dangerous.

3.2 Modeling Segment Real-Time Operating Safety Evaluation

When analyzing segment real-time operating safety, we pay more attention to the safety of all vehicles on a segment, instead of the safety of one or several vehicles. Because even if the driving risk of one or several vehicles is very high, the current technology could not deal with them individually. While the entire driving risk of all vehicles on a segment is very high, administrators could then take some measures, such as speed limit, entrance controlling and traffic diverging, to improve the operating safety of this segment.

Speed and density, two of the elementary parameters of traffic flow, are the significant indices for safety evaluation. Speed represents how quickly traffic flow passes through the given segment, and density denotes how many vehicles are passing that segment. The analysis of single vehicle driving safety shows that the fault tolerance required by different traffic condition is different too. So the traffic condition needs to be determined first.

Suppose the length of a segment is L (m), and then the longest distance l (m) that could be seen by driver is:

$$l = \min(S_l, \frac{\int_0^L S_L dL}{L})$$

(4)

where: S_l ——visibility(m);

         S_L ——spacial sight-distance (SCSD) (m).

Equation (4) shows that the longest distance that could be seen by driver is the minimum value of visibility and SCSD. Because the value of SCSD on each position of a segment might be different, the expectation of SCSD is used here.

Suppose the longest distance l (m) that could be seen by driver is known, the limit situation should be considered. If every following driver could just see the leader vehicle's rear, then the space headway is:

$$S = l + \overline{h}$$

(5)

where: $\overline{h}$ ——average length of vehicle (m).

The threshold of density is:

$$\rho_0 = 1000 / (l + \overline{h})$$

(6)

The density ρ (vehicle/km) could not be detected directly by loops on freeway. Suppose the length between two loops is L (m), set volumes detected by those two loops during time interval t_{i-1} t_i are q_i and Q_i. If there are no entrances on this segment, and two loops start to detect from the moment of zero flow, then the density at moment t_i is:

$$\rho_i = 1000(\sum_1^i q_j - \sum_1^i Q_j) / L$$

(7)

If $\rho_i < \rho_0$, then driver cannot see the leader vehicle, and the traffic condition is free flow. On the contrary, if $\rho_i \geq \rho_0$, then the rear of leader vehicle could just be seen by following driver, and the traffic condition is non-free flow.

After determining the traffic condition, in order to know the fault tolerance of the distribution of speed and density at this moment, the critical speed V_0, V_1, V_2 (km/h) in non-free flow and V_0', V_1', V_2' (km/h) in free flow are calculated based on safety grades 1, 2, 3 and 4.

$$V_0 = \frac{1000 - 2\overline{h}\rho}{0.278\rho t}$$

(8)

$$V_1 = \frac{1000 - \overline{h}\rho}{0.278\rho t}$$

(9)

$$V_2 = \frac{1000}{0.278 \rho t}$$

(10)

$$V_0' = \frac{1}{2}\left[-70.612(f \pm g)t + \sqrt{4986.054544(f \pm g)^2 t^2 + 1016(f \pm g)(l - \overline{h})} \right]$$

(11)

$$V_1' = \frac{1}{2}\left[-70.612(f \pm g)t + \sqrt{4986.054544(f \pm g)^2 t^2 + 1016(f \pm g)l} \right]$$

(12)

$$V_2' = \frac{1}{2}\left[-70.612(f \pm g)t + \sqrt{4986.054544(f \pm g)^2 t^2 + 1016(f \pm g)(l + \overline{h})} \right]$$

(13)

Set v_j (km/h) is the speed of the j th vehicle that pass through the upstream loop of a given segment, then the approximate space mean speed of all vehicles on this segment at moment t_i is:

$$\overline{V_i} \approx \sum_m^n v_j \bigg/ (n - m + 1)$$

(14)

where: $m = \sum_1^i q_j - \rho_i + 1$, $n = \sum_1^i q_j$.

According to the traffic condition of the segment at this moment, its safety grade could be obtained by comparing space mean speed with the relevant critical speed.

If $\overline{V_i} < V_0$ or $\overline{V_i} < V_0'$, its real-time safety grade is 1.

If $V_0 \leq \overline{V_i} < V_1$ or $V_0' \leq \overline{V_i} < V_1'$, its real-time safety grade is 2.

If $V_1 \leq \overline{V_i} < V_2$ or $V_1' \leq \overline{V_i} < V_2'$, its real-time safety grade is 3.

If $\overline{V_i} \geq V_2$ or $\overline{V_i} \geq V_2'$, its real-time safety grade is 4.

From Equation (8)-(13), it could be found that in non-free flow, the critical speed is in inverse proportion to density. When traffic density is high, flow should keep a low speed to ensure safety. When traffic density is low, flow could be in a relative high speed without impacting safety. In free flow, the critical speed is proportional to visibility and friction coefficient. When driving under fine weather and good alignment, vehicle could run in a high speed safely. However, when fog, rain or snows result in low visibility and low friction coefficient, vehicles must be in a low speed in order to ensure safety.
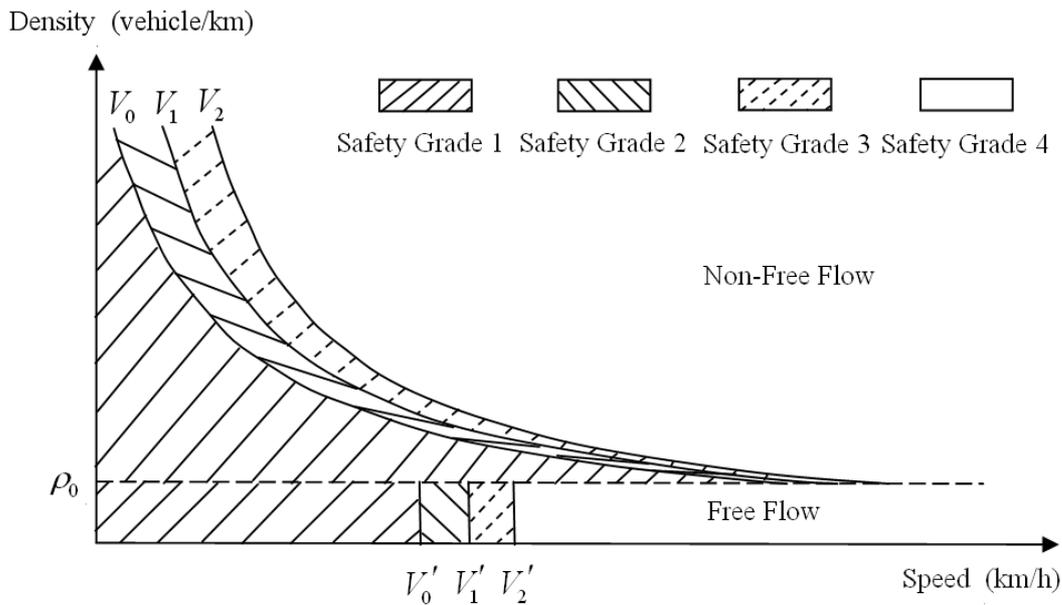
Figure 1 Freeway Real-Time Speed-Density Safety Grades

Based on the segment real-time operating safety evaluation model presented in this paper, the figure of freeway real-time speed-density safety grades could then be drawn and shown in Figure 1. To evaluate the real-time operating safety of a freeway, the critical density ρ_0 should be calculated first, and then the traffic condition can be ascertained. Finally, the safety grade could be determined according to the distribution of speed and density in Figure 1.

4. Simulation and Verification

According to the freeway real-time operating safety evaluation model proposed by this paper, there are four steps of the entire process. Firstly, collecting static and dynamic data; secondly, determining traffic condition; thirdly, evaluating freeway operating safety; and finally obtaining safety grade of the whole freeway. It is shown in Figure 2.
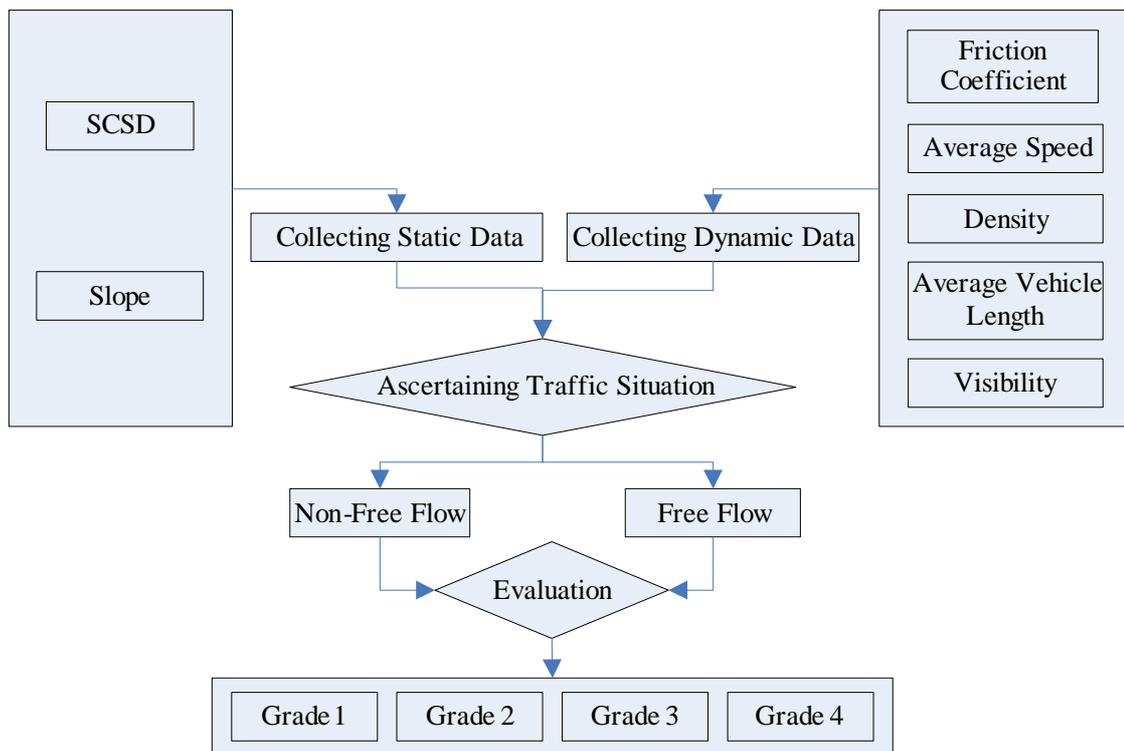
Figure 2 Flow Chart of Freeway Real-Time Operating Safety Evaluation

In order to verify the model, the traffics on dual lane freeway are simulated through VISSIM 4.0 software. The span of loops is set as 1 km.

The low-density traffic flow and high-density traffic flow are simulated separately, due to the limitation of length, only the results of a 1km long segment in half an hour are presented. The values of density in Figure 3-Figure 4 represent the density of dual lane.
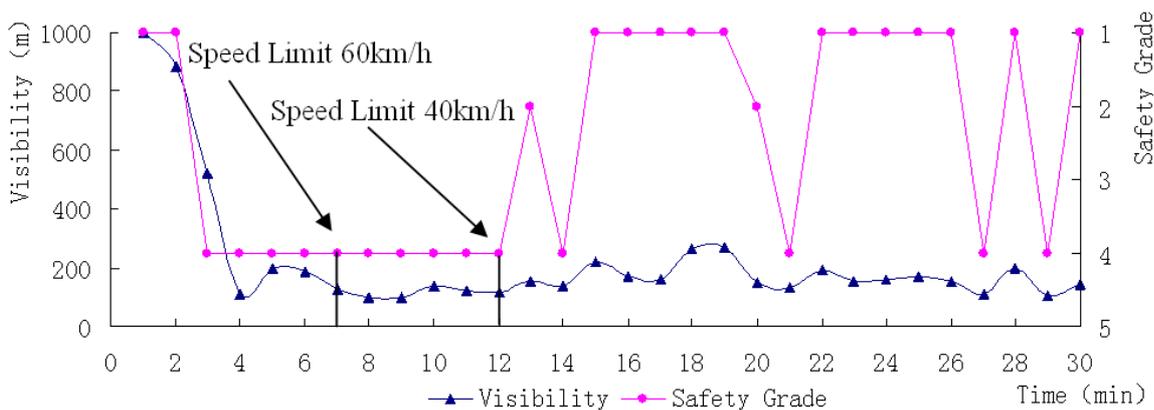
4.1 Low Density Traffic Flow

Because of the large capacity of dynamic data and the fussy processing of original data, only 10 min's data of a segment are taken as an example, and they were shown in Table 1. By them, the flow of freeway real-time operating safety evaluation is illustrated. To the segment, the expectation of SCSD is 682.5 m, and its surface friction coefficient and gradient are 0.3 and zero respectively.

In Table 1, the visibility and the average length of vehicle $\overline{h}$ are both the real-time data collected by diverse sensors. The density and the speed are calculated through equation (4)-(14) using the original data. Here, the speed refers to space mean speed of the target segment. According to our model, the threshold of density ρ_0 at a certain moment should be calculated firstly through Equation (4)-(6) based on the visibility, $\overline{h}$ and SCSD. Then, through Equation (8)-(13), the critical speeds in free flow and none-free flow under different safety grades at that moment should be computed respectively. Moreover, we determine the traffic condition at that moment by comparing the density with the threshold of density ρ_0.

At last, the safety grade of the segment at that moment could be obtained through comparing the speed with the corresponding critical speed. Then, through circulating the above process 1 time per minute, the real-time safety grade of the target segment could be known. Figure 3 shows the relationship between results and the dynamic data.

Table 1 the Real-Time Safety Evaluation on Low Density Traffic Flow

Time(min)	1	2	3	4	5	6	7	8	9	10
Visibility(m)	998	882	523	108	198	187	128	100	101	140
Density(veh./km)	7	10	3	3	3	3	4	6	11	11
Speed(km/h)	110.0	97.2	114.7	95.6	105.8	107.2	112.8	63.2	64.1	65.6
$\bar{h}$ (m)	4.4	5.6	4.4	6.5	6.4	4.4	4.3	4.3	4.6	4.5
ρ_0 (veh./km)	2.5	2.8	4.7	20.1	11.7	12.6	18.0	22.6	22.2	16.5
V_0 (km/h)	398.5	271.5	946.5	940.7	940.7	946.4	707.1	467.3	248.3	248.6
V_1 (km/h)	404.8	279.7	952.9	949.9	950.0	952.8	713.2	473.5	255.0	255.1
V_2 (km/h)	411.1	287.8	959.2	959.2	959.2	959.2	719.4	479.6	261.6	261.6
V_0' (km/h)	149.0	138.3	101.2	32.7	52.6	51.4	38.9	32.0	32.1	41.5
V_1' (km/h)	150.0	139.6	102.6	36.7	55.6	53.6	41.4	34.8	35.0	44.0
V_2' (km/h)	150.9	140.9	103.9	40.5	58.6	55.6	43.8	37.4	37.8	46.4
Safety Grade	1	1	4	4	4	4	4	4	4	4

As shown in Figure 3, the speed of traffic flow in low density is super high. With the decrease of visibility at the 3rd minute, the safety grade reduces accordingly. It means the fault tolerance is becoming bad at this moment, and the driving risk might be high. When taking speed limit of 60 km/h at the 7th minute, the density of traffic flow increases with the decreasing of speed, but the safety grade does not rise. Only when speed limit is set to 40 km/h at 12th minute, does the safety grade of this segment rise and the fault tolerance is improved. Figure 3 indicates that speed limit could efficiently improve the safety grade of low-density traffic flow under fog and ensure the required fault tolerance of traffic flow.
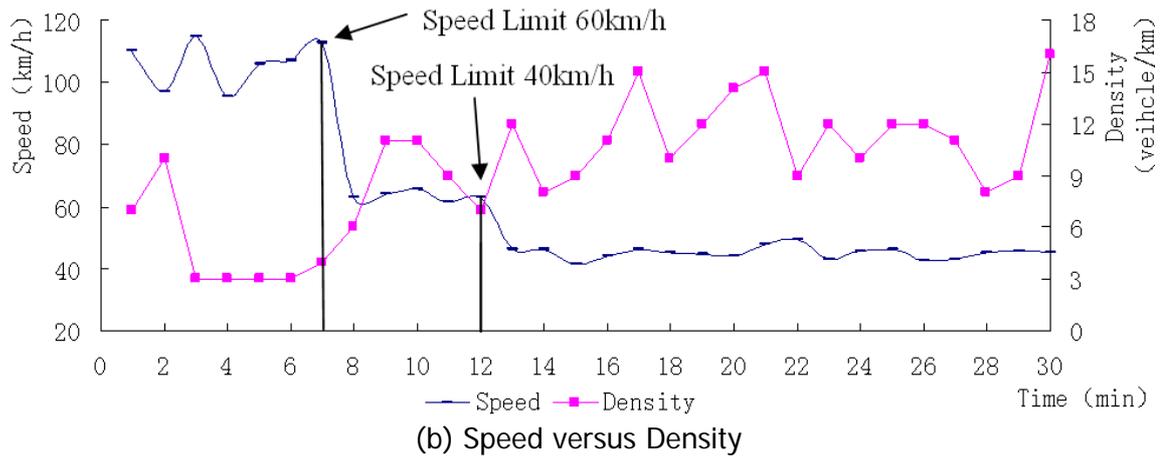

(a) Visibility versus Safety Grade

(b) Speed versus Density

Figure 3 the Real-Time Safety Evaluation on Low Density Traffic Flow

4.2 High Density Traffic Flow

The high-density traffic flow has the same segment condition as the low-density traffic flow simulation. Therefore, the expectation of SCSD is 682.5 m, and its surface friction coefficient and gradient are also 0.3 and zero respectively.

By the same way, the real-time safety grade could be known. Figure 4 shows the relations between results and the dynamic data.

Table 2 the Real-Time Safety Evaluation on High Density Traffic Flow

Time(min)	1	2	3	4	5	6	7	8	9	10
Visibility(m)	998	882	523	108	198	187	128	100	101	140
Density(veh./km)	48	44	33	33	36	52	28	34	87	82
Speed(km/h)	59.7	59.3	63.4	44.8	48.6	50.8	61.4	62.8	43.3	43.1
$\bar{h}$ (m)	4.9	4.6	4.6	5.7	5.7	5.0	4.4	4.8	5.1	5.1
ρ_0 (veh./km)	2.5	2.8	4.7	20.5	11.8	12.5	18.0	22.3	22.0	16.4
V_0 (km/h)	45.7	52.3	73.9	70.9	63.4	41.0	90.0	70.7	18.5	20.3
V_1 (km/h)	52.8	58.8	80.6	79.0	71.7	48.2	96.4	77.7	25.8	27.7
V_2 (km/h)	60.0	65.4	87.2	87.2	79.9	55.3	102.8	84.6	33.1	35.1
V_0' (km/h)	148.9	138.6	101.2	33.2	52.9	51.1	38.8	31.7	31.8	41.2
V_1' (km/h)	150.0	139.6	102.6	36.7	55.6	53.6	41.4	34.8	35.0	44.0
V_2' (km/h)	151.0	140.7	103.9	40.1	58.2	55.9	43.8	37.7	38.1	46.8
Safety Grade	3	3	1	1	1	3	1	1	4	4

As shown in Figure 4, the speed of traffic flow in high density is low, and flow is a little congested. When visibility decreases at the 3rd minute, the safety grade does not decrease because of congestion. With the farther increasing of density at 8th minute, jam becomes worse and speed decreases much more. It indicates that the fault tolerance of flow is bad, and the driving risk will be high. Only when the density decreases at 15th minute due to traffic diverging, does the safety grade of this segment rise and the fault tolerance is improved. Figure 4 indicates that the safety grade of high-density traffic flow is not affected greatly by visibility, but by the magnitude of density. High density will result in high driving

risk and low safety grade. Traffic diverging is proved to be a good measure to decrease the traffic density, increase the safety grade, and ensure the required fault tolerance of traffic flow.

(a) Visibility versus Safety Grade
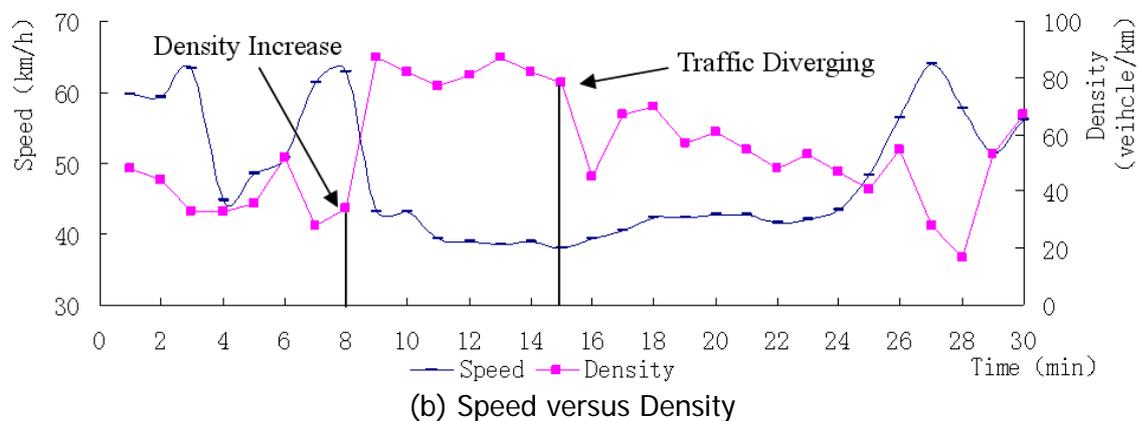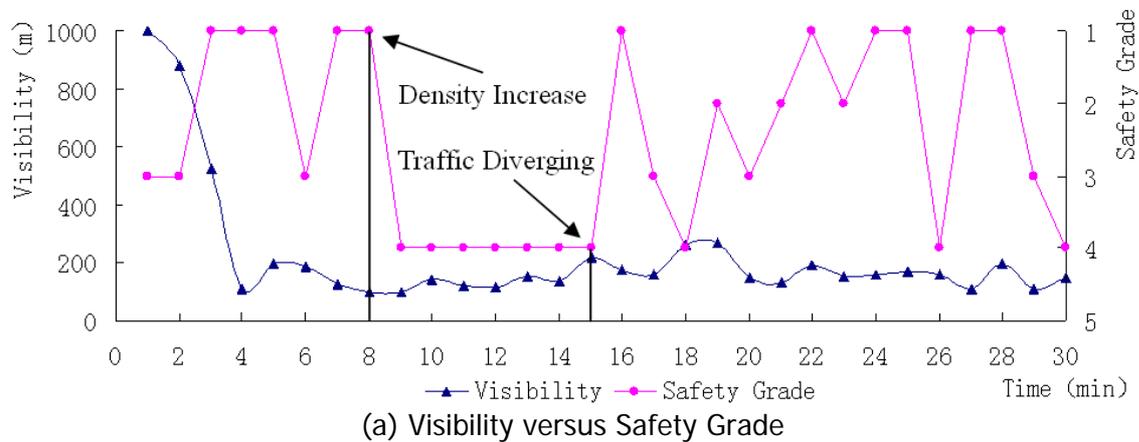

(b) Speed versus Density

Figure 4 the Real-Time Safety Evaluation on High Density Traffic Flow

The simulation results show that the freeway real-time operating safety evaluation model based on fault tolerance proposed in this paper could not only efficiently estimate the real-time driving risk of vehicle under different weather, road and traffic condition, but also evaluate the impact of management. It is feasible to be applied in traffic management and control. But another thing should be noted that this model needs large capacity of dynamic data. When original data is not enough, the results may be low precision and poor sensibility. Therefore, the model presented in this paper is more suitable for the freeway with complete information collection devices and high-level informatization.

5. Summary

The dynamic changing of weather, road and transportation all play an important role in the freeway real-time operating safety. Therefore, this paper, integrating the influences of the above three factors, defines the safety grades based on the fault tolerance of traffic flow, for the purpose of accidents avoidance. By analyzing all sorts of dynamic data collected by freeway monitor system, the real-time safety grade of freeway could be evaluated. The results of simulation show that the model could be used to not only estimate the real-time driving risk of vehicle under different weather, road and traffic condition, but also evaluate the impact of management. The evaluation results match reality well. Hopefully, this model could be a benefit to the safety improving and accident reducing on freeway.

Acknowledgement

Reference

Lijun Zhang, 2006. Research on Expressway Safe Operation Speed under Adverse Weather. Master thesis, School of Transportation Engineering, Tongji University, China.

Ministry of Public Security of China, 2006. Information Bulletin of the Traffic Accidents in 2005 by Ministry of Public Security. http://www.itsc.com.cn/ViewNews.asp?ID=7586

Wenwu Wang, Qiansheng Li, 2001. Freeway Safety Management. Beijing. 164-165.

Xiaoqiang Wu, 2000. Review and Expectation of the Intelligent Transpiration System. Journal of Foreign Highway 19 (4), 36-39.

Xiaoqing Huang, 2006. The Application of Traffic Simulation in Road Safety Appraisal. Master thesis, School of Transportation Engineering, Tongji University, China.

Zhiqing Yang, 2005. Evaluating Model of Road Safety Based on Information of Vision. Master thesis, School of Transportation Engineering, Tongji University, China.

Zhiyi Sang, 2001. The Prevention of Freeway Fog Driving Safety. Shanxi Science & Technology of Communications (1), 55-57.

Zhongmin An, 1999. Tutorial of Freeway Traffic Safety Management. Beijing. 216-218.

Table Legend

Table 1 the Real-Time Safety Evaluation on Low Density Traffic Flow

Table 2 the Real-Time Safety Evaluation on High Density Traffic Flow

Figure Legend

Figure 1 Freeway Real-Time Speed-Density Safety Grades

Figure 2 Flow Chart of Freeway Real-Time Operating Safety Evaluation

Figure 3 the Real-Time Safety Evaluation on Low Density Traffic Flow

Figure 4 the Real-Time Safety Evaluation on High Density Traffic Flow